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PROCEEDINGS

SECOND MEETING, FIRST HALF, 65TH SESSION

The Second Meeting of the First Half of the 65th Session of the Royal Aeronautical Society was held in the Lecture Hall of the Royal Society of Arts, Adelphi, W.C. 2, on Thursday, October 24th, 1929. The President (Colonel the Master of Sempill) was in the Chair.

The PRESIDENT: Captain Macmillan was very well qualified to read a paper before the Society on the art of flying landplanes and seaplanes. Presumably when he referred to landplanes he had in mind those of the conventional type, as distinct from those with rotating wings and other similar arrangements about which one had heard on occasions. He had had a very wide experience in the flying of all types of heavier-than-air craft of the ordinary varieties—landplanes, seaplanes and flying boats—and in addition had written several standard works. He was also Warden of the Guild of Air Pilots and Air Navigators, a body which was formed officially on October 19th, 1929.

THE ART OF FLYING LANDPLANES AND SEAPLANES

BY

CAPTAIN NORMAN MACMILLAN, A.F.C., A.F.R.AE.S.

Introduction

Since this paper is prepared at the request of the Council of the Royal Aeronautical Society—a body which represents in the main the scientific aspect of aviation—I have endeavoured in preparing it to remember that I must infuse into its composition something of worth to the technician as well as to the pilot. If I manage to convey to the former some of the problems which confront the latter and which are not quite the same as those with which he is himself faced, I may have rendered some small service in response to the honour which the Council of the Society has done me in asking me to undertake this duty.

Considerations of brevity force me to generalise to a considerable extent, and to generalise in the form of a graph I have had a curve prepared (Fig. 1) of the climb performance of the imaginary aeroplane on which all the other diagrams are based. It should be clearly understood that no one type of aeroplane is represented by these diagrams, but rather a composite machine, and one which by an adjustment of the speed range along the scale of miles per hour, either downwards or upwards, can be accommodated to suit the average aeroplane, whether light plane, military plane, transport plane, or racer. The actual scale selected for the slides is one which can be taken as representative of the average, fast military or high-speed transport aeroplane.

Fig. 1 is a normal method of depicting the climb performance of the aeroplane. There are two curves, one denoting the time to height and the other the rate of climb in feet per minute at all heights from sea level to ceiling. Some of the slides which follow are less conventional in their illustration of performance.

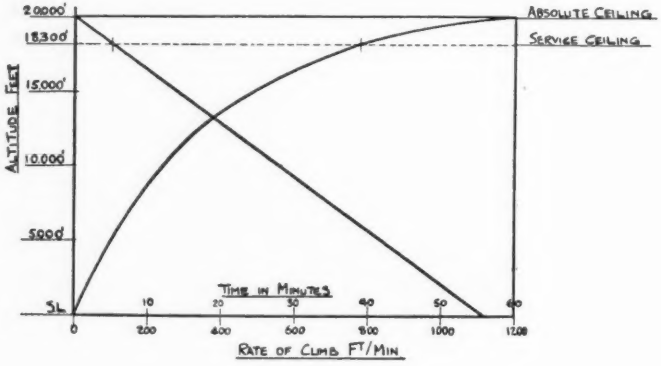


FIG. 1.

Flight is four-dimensional. For that reason it is not possible to depict the full capabilities of flight by means of plane or isometric geometry. The best that can be done is to contrive by the use of several diagrams to show several aspects of flight; when these are pieced together mentally they form a complete delineation of the subject; much as an architect has to use plan, front elevation, and end elevation to portray his building.

Nothing that the pilot does in flight can be accomplished without the measurement of time. The mathematician appreciates this, but without practical experience it is difficult for him to realise to what extent the pilot judges time in the flying of his plane. Yet knowledge of this vital feature in the art of flying is of vast importance to the aeroplane designer; it directly affects the loads which his structure must withstand, it affects the quality of the controls with which his aeroplane must be provided, it affects the alighting speed which, for the average pilot, can be considered a safe one.

If one considers the capacity of any aeroplane for the work for which it was designed one might represent it volumetrically in space as a thin slice cut through a pear at right angles to its vertical axis, and standing on the greater area as a base representing ground level. The depth of the slice and the diameters of the upper and lower surfaces should be proportional to the maximum distances which the aeroplane can travel vertically and horizontally in one hour at full throttle, the upper diameter representing this distance at the ceiling of the aeroplane. The result is somewhat curious and it upsets one's ordinarily accepted ideas of the performance of an aeroplane, a vehicle which one is apt to consider as possessing a great capacity for climb. This is the result of considering level speed in miles per hour or knots, and climb in thousands of feet. The proportional units of measurement for an average fast aeroplane of to-day are: Vertical axis 4, upper diameter 95 and lower diameter 150. If the upper diameter is measured in terms of the pilot's speed indicator reading it would fall to 70. In plane geometry this may be pictured as in Fig. 2.

This diagram represents the maximum geometrical capabilities of an average fast aeroplane depicted in terms of a unit of one hour of time—to the pilot a most important form of measurement, upon which he bases his air speed, his

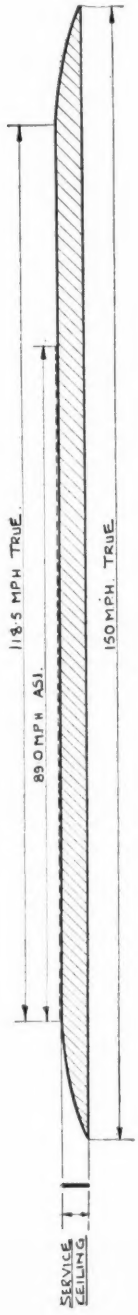

118.5 MPH TRUE.
89.0 MPH ASI.
150 MPH. TRUE.
SERVICE CEILING

FIG. 2.

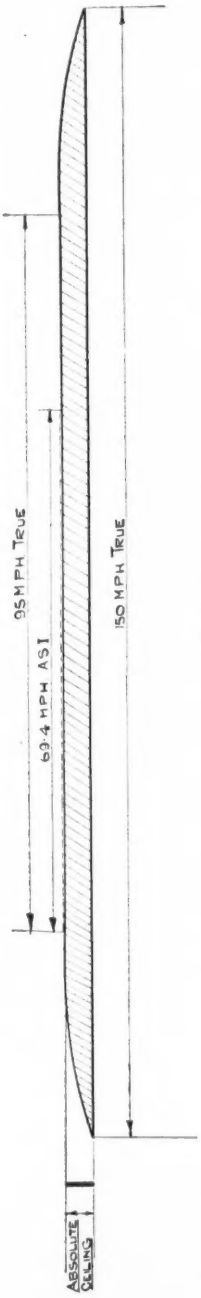

95 MPH TRUE
69.4 MPH ASI
150 MPH TRUE
ABSOLUTE CEILING

FIG. 3.

ground speed, and his fuel consumption. To the pilot, however, the service ceiling (which is fixed as the height at which an aeroplane develops a maximum rate of climb of 100 feet per minute) is more important than the absolute ceiling. The effect of transposing the service ceiling on the diagram is shown in Fig. 3.

These two diagrams depict the outside geometrical accomplishments of an average aeroplane when flying at full throttle on full climb or full speed level at sea level and absolute and service ceilings only, throughout a period of one hour. This is but one aspect of flight. In Figs. 4 and 5 we shall consider another.

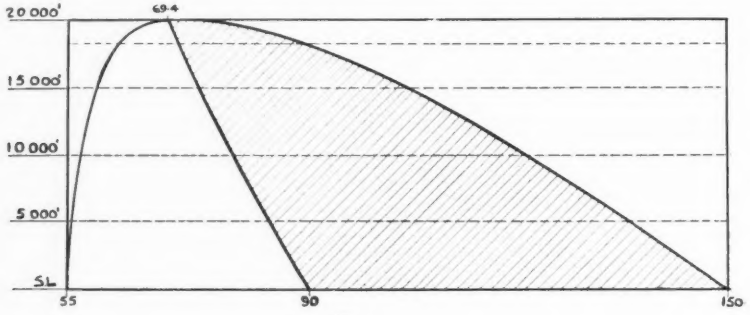


FIG. 4.

In Fig. 4 the abscissa represents the speed range of the aeroplane at sea level. The ordinate represents the maximum height to which the aeroplane can climb at full throttle. The line drawn between 90 m.p.h. and 20,000 feet shows the variation in speed of A.S.I. at which maximum climb is developed with change in height, until at the ceiling it represents the critical speed of level flight. The curve drawn between 150 m.p.h. and 20,000 feet shows the drop in indicated speed as height is gained. The curve from 55 m.p.h. to 20,000 feet shows the increase in indicated stalling speed as height is gained. It should be noted that this figure is drawn on the basis of full throttle throughout. Fig. 4 then gives some idea of the performance of the aeroplane as it appears to the pilot from his instruments.

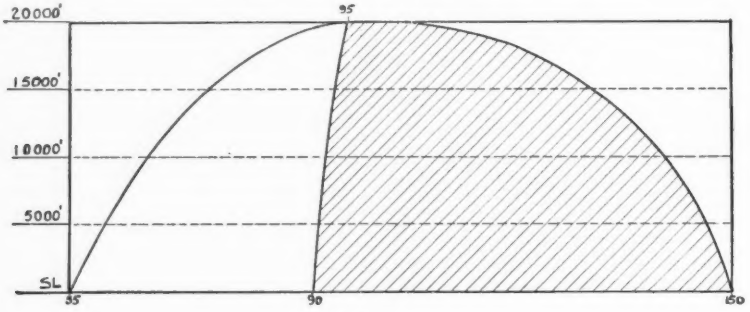


FIG. 5.

In Fig. 5 we see the same thing as it appears to the technician or the purchaser of the aeroplane, for in Fig. 5 the results obtained by the pilot flying the aeroplane have been corrected and represent the true accomplishments of the aeroplane.

The difference between Figs. 4 and 5 is somewhat remarkable. Even to the casual eye the value of height appears different, but the illusion is optical, for the scale is identical. Here then is one of the problems which the pilot has to resolve even as he flies along at any height above sea level. That complication alone is quite enough to call for study of the art of flying, but in itself it is relatively simple, for the diagrams depict solely the result in still air. If diagrams, Fig. 5, were drawn for flight in conditions of wind the difference in the results would be fantastic, for changes in wind direction and velocity at different heights would affect the regularity of the curves and disturb the whole figure. The sea level speed range would shrink or expand by the application of the up or down windage.

In each of the figures the portion between the curves of maximum climb and of maximum speed are shaded to indicate that for all normal flying that is the portion of the diagram within which the pilot flies. The unshaded portion is the least used section of the flight capacity of an aeroplane, and generally is only flown in when taking off and when approaching to land. I will have more to say about this part of flight later. Before leaving these diagrams, however, I would like to point out that Figs. 1, 4 and 5 are purely diagrammatic; Figs. 2 and 3 are geometric. The very briefest consideration of these diagrams, therefore, will convince one that the aeroplane is essentially a vehicle of speed. The impression that the aeroplane possesses a great capacity for climb is wrong and is purely relative. Because we live on one level we think that the aeroplane mounts to great heights, and the distorted pictures which our technicians draw of the climb of an aeroplane in the conventional manner of Figs. 1, 4 and 5 do not serve to restore our thoughts to a radical basis. It takes a powerful aeroplane to climb to more than four miles of vertical measurement in one hour, but when we call this 21,000 feet we are apt to assume a false ratio of climb to speed. It was for this reason that Figs. 2 and 3 were prepared upon a geometrical basis. The standard of a mile a minute which has been so eagerly sought after in the development of linear speed is still far beyond our present accomplishments in vertical speed, and a rate of climb of 5,280 feet per minute could be set up as a sea level standard towards which a section of aeronautical ingenuity might be attracted.

Coming to the last diagram, Fig. 6, we find an encompassment of the speed capacity of the aeroplane irrespective of its attitude in space. The figure is drawn on the assumption that all the speeds are realised at sea level, or rather in air of equal density, that density approximating to sea level conditions. The figure shows at a glance the complete flight characteristics of a typical aeroplane. The horizontal datum line is the line of level flight. It is composed of two radial lines branching from a central point which may conveniently be considered as representing the aeroplane when stationary on the ground. The other radial lines all indicate angles of inclination of the aeroplane's flight path to the horizontal, and the outer sweep of the curve cuts each radial line at the point of maximum speed which the aeroplane can reach at that flight path angle. Thus it will be seen that the maximum speed attainable is achieved in the vertical radial line, and that this terminal speed is not affected by the engine throttle setting, although the initial acceleration in a dive due to propeller thrust is clearly shown by the two curves depicting the engine on and engine off conditions. The curves to the left of the vertical line denote the characteristics of normal flight, while to the right of this line are those characteristic of inverted flight.

Details of interest which can be read off from this graph are :—

Left in Normal Flight.

1. The maximum angle of climb which can be sustained under engine power.
2. The speed at which maximum rate of climb is developed.

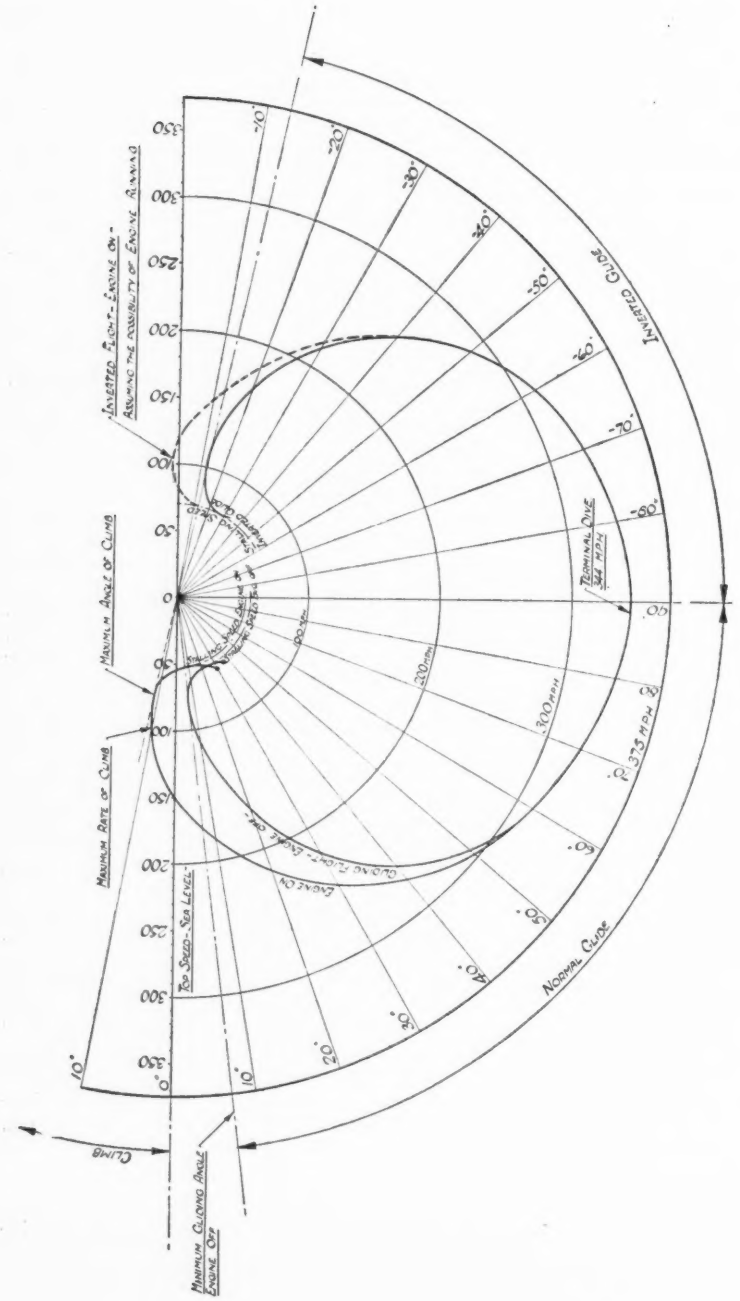

Inverted Glide
Normal Glide
Nominal Dive 344 m.p.h.
375 m.p.h.
300 m.p.h.
200 m.p.h.
100 m.p.h.
Climb
Minimum Diving Angle Engine Off
Minimum Rate of Climb
Maximum Angle of Climb
To Speed - Sea Level
Diving Flight - Engine On
Engine On
Engine Off
Inverted Flight - Engine On - Assuming the possibility of Engine Running

Fig. 6.

3. Maximum level speed.
4. Stalling speeds with engine on and with engine off. These differ slightly.
5. Angles of descent at stalling speed with and without engine.
6. Minimum level speed.
7. Speed range of the aeroplane.
8. Maximum speeds attainable with and without engine for any angle of descent.
9. Minimum gliding angle without engine.

Right in Inverted Flight.

10. Stalling speed when the aeroplane is upside down. Note that this is higher than when the aeroplane is right way up.
11. Angle of descent when stalled upside down with the engine starved for fuel and not firing.
12. Assuming that the engine can be made to run when the aeroplane is upside down.
    (*a*) Minimum level speed inverted.
    (*b*) Maximum level speed inverted.
    (*c*) Speed range inverted.
    (*d*) Maximum angle of climb inverted.
    (*e*) The speed at which the maximum rate of climb inverted is developed.
13. Maximum speeds attainable when inverted for any angle of descent.

It should be noted that all the curves are drawn on a basis of constant conditions of density and pressure, and that those taken are those pertaining to normal sea level conditions. The ultimate speed reached in the vertical nose dive can very seldom be achieved in actual flight, because the ceiling of an aeroplane rarely allows sufficient depth in the dive towards the ground to permit of acceleration to its terminal velocity before the pilot is forced to pull out to avoid crashing into the ground. Twenty-one thousand feet is just under four miles, and at a speed of one hundred and eighty miles an hour the dive to earth would be completed in eighty seconds. The curve shows the rapid acceleration at the commencement of the dive, especially when assisted by the engine, but the acceleration at high speeds is very much slower, as is shown by the curve flattening out at the bottom. This slowing down of the acceleration admits a time factor which in effect cuts the dive short before the bottom of the curve is reached. The maximum speed in the vertical dive is reached when the total air resistance is equal to the total weight of the aeroplane. This is the ultimate speed, beyond which no aircraft can pass.

With these six diagrams I have endeavoured to give a pictorial conception of what an aeroplane can accomplish in flight. Figs. 2, 3, 4 and 5 show instantly the distinct difference between the geometry to which the pilot flies in instruments against that to which the technician and the salesman refer on paper. For purposes of navigation and of bombing the pilot must have recourse to additional instruments which enable him to restore equilibrium between the diagrams, but this does not help the youthful pilot who has not properly realised how great is the difference between real flight and flight on paper, one who reads the manufacturer's performance tables, but who cannot transpose them into the pilot's instrumental readings. I would very much like to see every manufacturer who sells commercial aeroplanes quote in his performance the A.S.I. figures in parentheses, purely for the benefit of the pilot.

Flying divides into three distinct parts—

(1) The start or take-off.
(2) Fully air-borne flight.
(3) The alighting.

There are innumerable sub-divisions, but these are the three main features which naturally separate, like cream, milk and butter; the sub-divisions are like the many varieties of cheese. This paper is too short to consider every detailed aspect of flight and as it has to treat of seaplanes as well as landplanes I propose to cut out the cheese.

These three parts may be classified as follows:—Nos. 1 and 3 as ground flight, No. 2 as air flight. As everyone knows, the life of the pilot is relatively short. By this I do not wish to infer that early decease follows the commencement of a career in practical aviation, although this is sometimes the case. I mean that the pilot's flying life is counted in hours, and a hundred hours, although terrestrially reckoned only as four days, represent quite a long time in the air. If one considers the average length of a flight to be about thirty minutes and the average time of take-off and landing at about fifteen seconds each, then the ground flight experience of the average pilot is roughly one-sixtieth part of his air flight experience. Even allowing for the additional time devoted to ground flight in the preliminary stages, it is not likely that the hundred-hour pilot has much more than four hours of ground flight to his credit. This is why so many accidents occur near the ground to pilots who are young in air experience. They try to take to their wings too quickly, to soar upward into the skies where they can perform the satisfying evolutions of aerobatics before they have mastered the elements of ground flight.

I have no hesitation in saying that full consideration should be given by every individual pilot under instruction to the precepts of more experienced pilots who have acquired the art of flying. There is no branch of flying in which this advice is of such real value as in ground flying, where pre-flight knowledge gleaned from individuals and books can be turned to value during the early practice hours of the young pilot. In flying, to be forewarned is to be forearmed in reality against the possible mistakes in judgment which the embryo may commit. High up, in full flight, there is time to think what to do; low down, near the ground, there is rarely time to reverse a mistake even once. By far the greatest percentage of flying accidents is ascribed to lack of judgment upon the part of the pilot, and these accidents invariably commence with a mistake perpetrated at low altitudes.

The art of flying lies in the judgment of eye, the touch of hands and feet, and the synchronisation of all to one end. The air pilot must decide what he will do, then do it, not change his mind at the last moment. The vacillating individual should not fly, if he values his life, unless he has first conquered this failing.

In the case of the aeroplane with a speed range of 55 to 150 miles per hour, I classify ground flight as from 0 m.p.h. to 75 m.p.h., and full air flight from 75 m.p.h. to 150 m.p.h. Flight at the latter speeds should normally bear no connection whatever with the ground. The pilot then should not consider the ground when in full flight at any reasonable height, although when circumstances—such as weather, high mountains—force him to fly near the ground he must regard it. The horizon, which plays an important part in the pupil's lessons, is an excellent datum line about which the instructor can display the functions and values of controls when on the turn, and from which he can direct the aeroplane's attitude to the horizontal when on the glide, but it must not be carried too far into the pupil's post-training flying. Actually I would recommend that final lessons on advanced types of aeroplanes should include flying without regarding the horizon. Of this type of flight there are several varieties —the first, the aerobatic flight of single-seaters in fighting flying; the second, formation flying in which one's aeroplane is flown in relation to another; the third, the skilled pilot's flight during which he sometimes rides the air regardless of horizon and instruments, flying solely on a sense of balance and of touch;

the fourth, the horizonless flight of the test pilot and the pilot flying blind, both of whom must fly by instruments; the fifth, pure navigational flying.

Although not generally realised this horizonless aspect of flight is very important in the early stages of ground flight, because the glide to the landing on strange aerodromes may bring the nose of the aeroplane below a false horizon, such as a belt of trees or a range of hills, or a bank of clouds or mist, and throw out the inexperienced pilot's judgment, while on a prolonged glide the whole aspect of the earth's surface can make an apparent change of angle, the ground appearing to tilt up as one approaches, so that the horizon appears relatively higher, which can very readily induce instinctive deceleration quite low down, with a consequent possibility of stalling at low heights.

Again, modern streamlines and wing sections have so diminished head resistance and increased lift that sometimes the nose of the aeroplane actually rises above the horizon upon the slow glide, when too rigid an adherence to the principle of nose so much below the horizon will make the inexperienced pupil approach the landing with greatly excessive speed, when the optical change of the angle of the earth's surface will add still more to his confusion as to what he must do with his surplus velocity.

I shall now pass to a more particularised study of the flying of landplanes in general.

The take-off: This, the period of transition from rest to air-borne flight, should never be treated with carelessness. The pilot should always be conscious that he is performing an act which requires great concentration. Many pilots, accustomed to taking-off hundreds or perhaps thousands of times, affect an attitude of indifference to the act of acceleration to flying speed. It becomes instinctive. Now, no matter how accustomed one has become to the act of taking-off, the few seconds which are entailed in this process should always be considered worthy of the deepest attention. Wind direction, the position of all aeroplanes flying in the neighbourhood, any obstructions ahead of the clear stretch of aerodrome, should all be noted, together with the instrument readings which matter—oil pressure and fuel pressure or gauge should always be glanced at just before opening the throttle after taxying out into wind; the setting of the adjustment for the tail should also be verified. It is understood that the pilot has already satisfied himself that the engine is functioning correctly on the tarmac. The attitude of the aeroplane when standing on the ground should be noted mentally because that indicates something of the stick position required to raise the tail when the engine is first opened out; it also provides the pilot with the exact position which the aeroplane must be compelled to adopt at the precise moment of alighting to make a three-point landing—the aim of the pilot who prides himself upon his landings. It ought also to be the aim of the designer who prides himself upon his skill that the aeroplanes he turns out do make their slowest possible landings when at the three-point angle. This is a matter which concerns the correlation of fuselage angle, wing angle to fuselage, wing section, tail weight, tail volume and elevator volume. It is not the easiest part of a designer's life to so adjust the varying requirements of a new type that they will enable even the relative skill of different pilots to be so accommodated as to achieve a common verdict that the new machine is an easy one to land. It is sometimes true that the pilot is blamed when the designer is the culprit.

Before taking off, the compass direction of the wind upon the ground should be noted as a mental record of the wind direction on the ground, which may not be the same as that of the geostrophic wind. Drift readings of the latter, while necessary for the keeping of correct compass courses when flying above 1,500 feet, do not indicate the ground wind direction which should never be unknown to the pilot because the sudden need for a forced landing may not give him time to find it out and thus augment the difficulty of making a safe

alighting. If about to set out on a cross-country flight, the state of the sky becomes a matter of more than casual interest.

Always before going into the air, and without any exception, the pilot should note that all his controls move in the correct direction and to the full extent of their travel.

The characteristics of aeroplanes vary in the take-off, but to a less degree than in the alighting. Apart from the obvious effects of changes of load and centre of gravity, the main causes of differentiation which affect the pilot are the following: Power/weight ratio, airscrew characteristics, tail skid load and tail plane and elevator volumes, wheel resistance, head resistance, wing section and wing loading. I have placed these factors in the order in which they affect the take-off.

Let me dwell briefly upon them one at a time. The effect of ample power is obvious. The design of the airscrew plays a most important part in the ease of take-off; immediate acceleration can be obtained from a suitable airscrew, in the production of which engine gear ratio and revolutions are most important; one cannot hope for rapid take-off from a direct-drive, high-revving airscrew which may be stalled until a forward speed of something like 40 m.p.h. is reached; with this type of airscrew one can feel the instant increase in acceleration which denotes the passing of the critical point; best take-off is obtained by forcing the tail up as quickly as the thrust will lift it until the fuselage reaches the angle of minimum resistance to the forward passage of the aeroplane; in this way the poor thrust is utilised to the best advantage; sometimes with this type of airscrew initial acceleration is best achieved by deliberately not opening the throttle to the maximum until considerable forward speed is gained; best results are realised by taking-off dead into wind. There is not much that the pilot can do with defective airscrew design other than this, and the problem, when it arises, must be dealt with by the designer of airscrew and perhaps of engine.

With tail-skid load and tail surface volumes the matter is quite straightforward. If the pilot is unable to lift the tail-skid from the ground as soon as he opens the throttle the additional drag lengthens the accelerating run. In this case the pilot should have the stick hard against the forward stop before he opens the throttle and should always take-off on a down gradient if that is possible. The remedy is again one of design.

Wheel resistance produces a dual problem, one of slow speed and one of high speed. On soft ground, when the wheels tend to bog, the tail must be kept low to reduce the load on the wheels and to make the aeroplane less likely to tip upon its nose and damage the airscrew; with increasing speed, however, the tail must be allowed to rise for two reasons; first, to reduce head resistance which becomes more and more important as speed increases, and second, to enable the pilot to assume effective elevator control should the aeroplane run over patchy ground of varying degrees of softness.

Wing sections make a difference to the take-off control required by the pilot. The thin wing with a critical stall is generally best handled by being forced to assume the attitude of minimum head resistance throughout the complete take-off run and held there until minimum flying speed is actually exceeded when the well designed aeroplane will fly herself off. Length of run and other considerations may call for slightly different handling in special cases. The thick wing, when not too heavily loaded, can be eased to a decided positive angle while running along the ground, and this will be found to reduce the length of run considerably by reason of the reduction of wheel resistance which accompanies the proportion of lift taken by this type of wing at speeds below flying speed. With very high loadings, when the speed range is limited and the climbing angle is low, the take-off calls for very great skill upon the part of the pilot. It may well be that a variation of more than two degrees on either side of a definite angle of best lift/drag ratio will prevent the aeroplane from taking off at all;

in this case no oscillation to feel the aeroplane off the ground is permissible; the correct take-off attitude must be assumed as quickly as possible and maintained scrupulously throughout the run.

When the thrust obtainable is high, as on aeroplanes of light power loading, the question of take-off is easy and may be one solely of counteracting the effects of torque and slipstream by means of aileron and rudder, actions which soon become automatic in a pilot's life.

When the pilot's view makes it feasible I advocate sitting centrally in the aeroplane and facing and looking dead ahead. Any other attitude tends to make the pilot take-off slightly out of the straight course or with one wing slightly down.

Throughout the take-off run and during the initial part of the climb it is very necessary to listen attentively to the engine. There is no more dangerous situation in the air than that when the engine cuts out dead after having taken off and risen a few feet into the air. If there is any change of note from the engine the pilot should immediately reduce his angle of attack in readiness for a complete engine stoppage and the need to assume a gliding attitude to prevent a stall. The advice never to turn back under such circumstances is very sound because the judgment required to do so successfully must be superfine.

Fully air-borne flight is easy, infinitely easier than the driving of a motor car. There is little to add to what has already been indicated earlier in this paper about the discrepancy which exists between indicated speeds and actual speeds. With regard to height there are two sources of error which may arise in the pilot's computation of his height. The first is the need to know the height above sea level of the ground over which he flies in relation to that from which he started and at which, presumably, he set his altimeter to zero. This information can be obtained by determination of one's position on the map and the reading of the heights given thereon. A second more serious source of error is that caused by the horizontal variation of atmospheric pressure, which affects the reading of the altimeter. The only means the pilot has of determining this is by studying the weather chart and its tendencies over the route upon which he is going to fly. One millibar is equal to 30 feet, and a deep depression could produce a variation of as much as 1,000 feet in the reading of the altimeter, in which case the pilot would be flying instrumentally 1,000 feet higher than his true height.

In fully air-borne flight the worst predicament in which the pilot can find himself is the spin, and of spins the worst variety is the inverted spin in which the accelerations on the aeroplane are acting to eject the pilot from his cockpit. Fortunately, modern design has reduced the danger of spinning to a very great extent. The spin always follows the stall and the character of the stall has been very materially altered in recent years by the adoption of the Handley Page slot. The aeroplane fitted with the slot is much more difficult to stall and consequently more difficult to spin. The slot does not eliminate the spin, but it makes it almost impossible to spin involuntarily, for all three controls must be applied to the maximum to produce the spin when the aeroplane is in a stalled condition; that this could happen involuntarily is very improbable. The slot furthermore reduces the speed of rotation when in the spin and makes the recovery more rapid. These remarks relate to the effect of the slot in the normal spin. I do not know precisely what the effect of the slot is in the inverted spin, nor have I ever met anyone who has been able to tell me, but it would appear that in the inverted spin the slot will not have the same effect and that it may not have any effect until the aeroplane is well through the manœuvre of recovery, and restoration to normal airflows and accelerations has been achieved by the pilot. In the normal spin, however, I have found on one machine that aileron control alone was sufficient to bring the aeroplane from the spin condition into the spiral, and this I have never found on any aeroplane not fitted with slots. Just as

every motor car is better when fitted with four-wheel brakes, so is every aeroplane better when fitted with slots. Nevertheless, every pilot should know how to spin and how to recover from both the normal and the inverted spin so that in emergency he can act without hesitation.

The rudder is the control which is most effective in checking the initial entry into a normal spin; the elevator is the control which is most effective in making the initial recovery when the aeroplane is actually spinning. Recovery from the normal spin is secured by placing the control column central laterally and forward of neutral fore and aft and at the same time centralising the rudder. Aeroplanes which are refractory in spinning may require the stick to be pressed hard forward against the instrument board together with the application of almost full opposite rudder, while a few really vicious ones require these control movements to be made with violence. Modern design ought, however, to preclude such dangerous spinning properties in present-day aeroplanes.

The inverted spin is entered from a stall when upside down with the stick forward and rudder applied. Recovery is effected by centralising the rudder and bringing the stick centrally behind the neutral position. The docile aeroplane then returns to a normal glide. The refractory aeroplane may require violent control movements from the inverted spin control positions to the normal spin positions and, then, when the aeroplane answers, a second control movement to the normal spin recovery positions.

Only when absolutely necessary should opposite rudder be applied in the recovery from spinning, because it makes possible the reverse-handed spin if insufficient elevator is used, and insufficient time allowed to effect complete recovery to the non-stalled glide. As a general rule the stable aeroplane is unstable when inverted and consequently is less likely to remain upside down. This makes the recovery to normal flight easier to accomplish, and is a strong argument in favour of positive stability.

The alighting must be divided into two parts; first, the approach, and second, the actual alighting. The approach is the more difficult. It must be varied according to the characteristics of the particular aeroplane, and to meet the conditions encountered; these are, wind, ground over which the approach has to be made, and the size and shape of the aerodrome and the obstructions which lie about its periphery. Generally speaking, it is always better to overshoot in the approach than to undershoot. The latter involves the use of engine which instantly changes the wing angle of attack and the angle of glide and makes the actual alighting more difficult to accomplish neatly, whereas the former fault can readily be cured by the use of the sideslip which has the advantage of improving the view of the landing field. The method of making the approach will vary with the conditions under which it has to be made; sometimes the glide can be made downwind finishing with a 180 degrees turn into wind; this is the favourite method of alighting of the common crow, who accomplishes such landings with the ease of a finished artist; the swan, however, heavily laden and clumsy, always approaches with great care and exactness, obviously afraid of damaging himself by a clumsy landing on the water; I have never seen a swan alight on land. A very great deal can be learned about methods of approach from a study of the ways and means adopted by the different birds and I would counsel all students of the art of flying to profit by the simple means of observation, not only of birds, but by observing the landings of aeroplanes, particularly in regard to the approach.

The alighting is a simple matter if the approach has been properly made. If the approach is made too slowly, particularly with a heavy aeroplane, the pilot may find it difficult to get the tail down; there may be an observable tendency for the aeroplane to glide into the ground. The reason for this is simple. The changing of the aeroplane's attitude from the glide to the three-point absorbs a certain amount of energy. That energy is supplied by the moment resulting

from the upward movement of the elevator. The absorption of this energy causes the aeroplane to slow down. If, however, the aeroplane has previously been slowed to the point of stalling the surplus energy does not exist to provide the requisite moment, and the aeroplane simply does not flatten out. At slightly higher speeds this tendency is modified by the centrifugal effect resulting from the change of flight path. Assuming that the wing is just able to provide slight increased lift due to the change in flight path and angle of attack, centrifugal force then acts to destroy this lift and produce a heavy landing. At still slightly higher speeds the wing lift resists the centrifugal loading, which then serves to restore a portion of the lost momentum, in which case the aeroplane will be found to zoom slightly after the flattening out. The slowest possible alighting is the one which takes advantage of this last bit of energy. With some aeroplanes this will reduce the alighting speed by some two to four miles per hour. If one watches the skilled bird flyers alight, one will see them take advantage of this natural law. The correct inter-relation of these several factors can alone enable the pilot to accomplish the best possible landings. It should be noted that this zoom is not the violent zoom due to a badly executed approach at excessive speed. The speed required in excess of the stalling speed for different aeroplanes can soon be found in practice, and the pilot flying a strange type for the first time can assess the best speed by flying very slowly at a reasonable height and finding the effect of the elevator upon the pitching movement of the aeroplane. This detail must not be confused with longitudinal instability, for the longitudinally unstable aeroplane may quite possibly be easier to land from a slow approach speed than the stable aeroplane, although the required stick movement then becomes extremely critical. This can readily be proved by testing landings with a stable aeroplane loaded well aft so that the shift of the centre of gravity produces a less positive restoring moment from the tail surfaces.

Different wing sections require different handling. With the high-lift wing the preliminary flattening-out should be commenced considerably higher from the ground than with the thin wing. With the latter course elevator action upon the part of the pilot is always more effective to recover at the last moment from a bad approach, particularly one in which the speed of approach has been allowed to drop too low. The high-lift wing exceptions to this rule are generally poor aeroplanes.

Landing is usually best accomplished by looking well ahead of the aeroplane. Looking close ahead upsets the timing and makes landing more difficult to carry out consistently.

The last part of this paper has to treat of the flying of seaplanes. So far I have used the term aeroplane throughout, because most of the matter has been applicable to both land and sea planes. In the air the seaplane can be considered in the same way as a landplane. It is somewhat more clumsy, its speed range is usually less, and its manœuvrability somewhat poorer. In other respects its behaviour is similar. Any pilot who can fly a landplane can fly a seaplane in the air. The real difference between the types arises on the water, and the pilot who has experience of the water handling of yachts or motor-boats will not find the water handling of seaplanes so difficult as the pilot who has no such experience. The seaplane, however, has this disadvantage on the water—it has no keel, and consequently is more subject to wind drift and to list, especially since there is no means of reducing the large expanse of wing surface exposed to the wind. The monoplane, particularly the low-wing monoplane, with its reduced side surface compared with the biplane, and its lower vertical centre of gravity compared with the high-wing monoplane, is the least subject to the effects of wind, and, therefore, other things being equal, the best type, and the easiest for the pilot to handle.

It is in the crab-wise movement on the water due to the alignment of the seaplane necessary to accommodate the triple forces of wind and water and air-

screw thrust that the seaplane is most distinct from the landplane, and the judgment required of the seaplane pilot to offset the effects of wind and tide is a speciality of his own, of which he is justly rather proud. Nor is it something which can readily be acquired from books. It requires practice, and, above all, commonsense.

The take-off of a seaplane is different to that of a landplane. The water forces on the floats or hull are quite different to the loads on the wheels of a landplane; perhaps the nearest approach that the landplane pilot ever gets to the take-off of a seaplane occurs when he is forced to fly from very sticky ground on which his wheels alternately stick and free. The seaplane pilot must hold the nose of the seaplane well up when he first opens the throttle to cause the water to break as far aft as possible and so keep the airscrew as free as possible from spray. This critical point is usually passed fairly quickly, and at about 15 to 20 knots the seaplane rides out from the partly displacement-supported condition to the hydroplaning condition. At this point there is frequently a change of stick position from aft to forward, and if thrust horse-power is low the crossing of the hump, as this is called, may well require very great skill to accomplish.

Once the seaplane commences to hydroplane, acceleration is rapid because the water resistance falls immediately. Towards the end of the hydroplaning run it builds up again and the thrust available again becomes very important. The pilot can do a great deal to assist the take-off by forcing the floats to adopt the angle of minimum resistance through correct use of the elevator. In some seaplanes which I have flown this angle has been so critical that failure to reach and maintain it meant failure to take-off. To-day, however, float design and engine development have reached a stage which renders the take-off infinitely easier than it was in past years. In rough weather the skilled seaplane pilot carefully watches the run of the sea and chooses the moment to open the throttle with a view to crossing the critical, dirty period before the hydroplaning point in the smoothest possible water. In rough water it pays to get the seaplane into the air with the minimum run, but the pilot must be careful that he does not get thrown clear of the water before he has reached flying speed, otherwise the seaplane might fall back, stalled, into the trough of a sea and suffer serious damage.

The alighting of a seaplane does not present problems materially different from those which accompany the alighting of a landplane. On smooth water there is no difference between the landing of a seaplane and the landing of a landplane on land, except that it may be more difficult to judge height above the surface of the sea. In rough weather the matter is otherwise. Then the seaplane pilot has to alight on a surface the state of which would appal the average landplane pilot. The seaplane pilot must come down on to the water with the minimum forward speed, and touch ever so slowly just on the crest of a wave. Misjudgment will cause the seaplane to fall into the trough, when the next wave will sweep the seaplane and do damage. Alighting too early upon the wave crest will send the seaplane upward high into the air to fall heavily in a stalled condition into the turmoil of the sea and possible wrecking by the waves. The seaplane pilot is fully justified in taking pride in the skill which he displays in the handling of what is, for sea work, a relatively clumsy apparatus.

Discussion

The President: It was perhaps curious that the Society had never had presented to it before, in the 65 years of its existence, a paper on the art of flying. Many of Captain Macmillan's conclusions as to the care and handling of seaplanes were probably come to during the six days he drifted about on a wrecked seaplane in the Bay of Bengal, for 52 hours of which he had clung to the floats. He must have had plenty of food for thought in regard to the handling

of seaplanes under a variety of conditions. It would be well if the information given in the paper could be supplemented by details with regard to the handling of lighter-than-air craft. The paper might also be expanded by someone who was qualified to deal with the autogyro.

The question of piloting is considered seriously by the Society and it is laid down that one of the qualifications that may be advanced by any one applying for Associate Fellowship would be experience of piloting over a period of at least two years. Then, for example, those desiring to be elected a Fellow or Member may advance as a qualification the fact that they have had 10 years' experience of flying.

Long before the Society came into existence, however, there were others who appreciated the fact that flying was an art and some interesting ideas about the year 1750 may be gleaned from studying Dr. Johnson's "History of Rasselas," Chapter VI.

He called upon one of the Vice-Presidents of the Society, Lieut.-Colonel Moore Brabazon (who was the first British subject to fly in a power-driven heavier-than-air machine, on about May 2nd, 1909) to open the discussion, remarking that it was appropriate that Lieut.-Colonel Moore Brabazon should be present to hear the reading of the paper.

Lieut.-Col. MOORE BRABAZON: A period of not less than 20 years separated modern flying from his own; consequently there was little he could contribute to the discussion on the paper. He recommended the paper to all beginners. Commenting upon Captain Macmillan's quarrel with the scientists, he said he was always very keen to back up the practical man against the scientist.* After all, in physics, which was the science which tried to help one in ordinary life, one had seen the scientists go completely off the rails. In modern physics Heisenberg had stated that the position of a particle could be determined, but never its speed, or *vice versa*. That was all very learned, but an awful lot of nonsense. Again, in regard to gravity, the great scientists had done away with one's old friend ether, and had stated that everything was determined by a curvature of space in the fourth dimension. It was all very well for them, but it was very tiresome for other people. The same thing was going to happen in aeronautics. The ultra scientists would say soon that there was no air, and that flight was a function of the curvature of the spine of a pilot, or some such thing. Well let one be charitable; let one admit that in the ultra scientist there was use, and in the ordinary practical aviator there was use also. But it was very difficult to attain a really happy marriage between the two, and to bring about that happy marriage one must find an individual who understood both departments of the subject. That was what was found in Captain Macmillan. In his paper he had fought the battle of the practical aviator very efficiently and it was to be hoped that he would be backed up in that, because the ultra scientist was not only glib with his figures but rather more glib with his tongue than was the practical man. All those on the side of practice, therefore, must congratulate Captain Macmillan upon having thrown down the glove to the scientist. They welcomed his paper particularly because he was an example of that happy marriage between the extreme scientist and the practical man.

Squadron-Leader REA: The part of the paper which interested him most was that concerning the relations between the designer and the test pilot. Captain Macmillan had pictured the test pilot as a more or less down-trodden individual; he did not agree with him there but thought it was well to emphasise the point that the designer might obtain more value from the experience of the test pilots by keeping more closely in touch with them and taking more advice from them when they criticised the machines produced. A pilot, when looking over a new machine, could very often point to things which he considered required improve-

* This, the preliminary part of the original paper, is not reproduced in the *Journal*.

ment, but if he put these matters up to the designer without being able to back up his opinions with a host of figures and a lot of "X" chasing he might find that his advice was ignored.

Air-Commodore WEIR: He believed it was realised generally that one of the least desirable features of the modern aeroplane was that it necessitated that the pilot must acquire a considerable amount of skill before he could handle it properly, not so much in the air, but during landing under unsuitable conditions, and in various emergencies. It was with a view to overcoming this particular difficulty that he had been interested particularly in the autogyro development. From actual experience of the autogyro he could say that it did away with the need for great skill on the part of the pilot, and if other features of it could be further developed it might have an interesting future. Perhaps that sounded rather like an advertisement, but he did wish to emphasise that anything that could possibly be done to minimise the standard of skill necessary in piloting would improve tremendously and widen the scope of the modern aeroplane. He had just returned from the United States, where he had found that a frequent topic of discussion was the fact that the skill required by the amateur pilot who bought a machine was rather beyond him. The light machines in the States were generally high-wing monoplanes, with rather fast landing speed, and the average amateur usually experienced a crash or two, due to bad landing, before he got thoroughly into his stride. As far as possible the efforts of designers should be directed towards remedying that situation.

Flight-Lieut. JENKINS: Discussing the problem of the relationship between pilots and designers, he advocated that there should be more pilots on the designing staffs of aircraft-producing firms. It was much easier for a technician to become a pilot than for a pilot to become a technician. One always felt sad when one saw a non-flying designer standing alongside the product of his brains, and probably of the brains of a few other people, and not fully comprehending exactly what the machine meant. Only the pilot could do that. He knew from experience how often a pilot found that he had great difficulty in explaining to a designer exactly what he wanted to convey. Perhaps it was a question of some lack of nicety in the controls, and the pilot often felt like saying to the designer, "If you could only take this machine up for five minutes you would know exactly what I mean." That was not always possible, of course.

It was perhaps to be regretted that Captain Macmillan had not had sufficient time to deal more fully with the practical side of flying. In the art of flying, aerobatics must take a high place—from the points of view of the fighting pilot, the test pilot, the exhibition pilot, and the spectators. The art of flying must include the carrying out of every manœuvre with the maximum skill and beauty. He was not certain what Captain Macmillan had meant when he had advocated strongly that the mental-cum-practical method of flight instruction should be adopted throughout our civil and where required military schools. Service pilots were given a very sound ground knowledge of the theory of flight before they began to fly. Did Captain Macmillan suggest that they should receive advanced instruction in flight theories? If so, he personally could not quite agree. He could not visualise the highly-skilled technician learning to fly more quickly than a man who was not highly skilled technically; too much theory during flight instruction would tend to prolong the period of instruction. Pupils might be instructed more deeply in the technical side after having become safe pilots, however, for they would then be better able to understand the application of theoretical principles. With regard to spins, pilots should experiment a great deal with the various types of aircraft they handled, in order to discover the quickest method of getting out of a spin. The method varied with different machines, but if they had discovered the quickest way to get out of a spin in any particular type of machine, they might in an emergency be able to save that extra half-turn or turn which perhaps would mean disaster. Discussing

Captain Macmillan's reference to the importance of the tail adjustment in regard to taking off, he considered it was just as important, if not even more so, during landing. If the pilot did not use the tail adjustment he might find that he had to push or pull on the stick when gliding in to land, and trouble might result. He considered that the best method was to use the tail adjustment until the machine was gliding in hands off, and if that were done probably a good landing would be made. The problem of flying without an horizon was important. In Iraq there was an aerodrome 3,000ft. up, with a range of hills about 2,000ft. immediately above it. He had seen a number of crashes there, all due to the pilots landing on the horizon. They had not "landed" 2,000ft. up, but perhaps 50ft. up, and had crashed. Again, it was perhaps not advisable to look too far ahead when landing. He disagreed with the suggestion that with high lift wings it was advisable to flatten out at a greater height than otherwise. His experience was the opposite. With most of the high lift wing machines he had flown—there was possibly one exception—he had found it best to bring the machine down at the normal gliding angle to about 2ft. from the ground. The angle of attack with high-lift wing sections changed the rate of glide very appreciably, and if one were gliding in at, say, 75, an alteration of perhaps one degree in the angle of attack might mean 40 suddenly, so that if one started to flatten out when too high up, one was liable to pancake.

Flight-Lieut. CHICK (an instructor at the Central Flying School): The truth of much of what Captain Macmillan had stated was appreciated amongst the Service personnel generally, and amongst the training personnel particularly. He did not agree with Captain Macmillan, however, that pupils should be taught to fly without making use of the horizon. If a pupil were not taught to make use of his horizon, he would rely on his instruments entirely, and it was a very bad thing to teach a pupil to do that. It was very important that a pupil should be taught to make use of an horizon, at any rate during instruction, in order to keep a steady air speed during turns, and he should be told that in misty weather he would probably not find an horizon, and that in such circumstances he must select a spot some distance ahead to make use of in place of it. It was very easy for a pupil with a little experience to use a spot on the ground or on a hill by which to judge the fore and aft attitude of the aeroplane, which governs his air speed, and which was the most important thing he had to consider, and particularly when landing in mist he could judge the landing by reference to a spot some distance ahead as an horizon, in conjunction with the spot at which he was directly looking.

Flight-Lieut. CULLEY: He would like to corroborate Captain Macmillan's statements with regard to the critical point. There was a particularly critical point at the take-off, and there was a tendency even for experienced pilots to become very careless about it.

Flight-Lieut. BRYER: Captain Macmillan had advocated that the pilot should look well ahead when landing, and Flight-Lieut. Chick had suggested that it was necessary for all pilots, except perhaps the very expert pilots, to select points so far ahead that they would act as an horizon. A pilot landing on the deck of a ship when there was a haze over the sea, however, had no horizon at all, and there was nothing by which to judge except a point on the deck fairly close ahead. He had come to the conclusion that the distance ahead at which to look was decided by the minimum distance at which objects could be taken in by the eye without becoming blurred by the rapidity of their apparent motion. When near the ground on an aerodrome sometimes one could see the actual blades of grass a few yards ahead, and judge one's height with reference to them, but at other times one had to look farther ahead, and could only judge by larger objects, a gully for instance, or *tufts* of grass. It all depended upon whether one was flying slowly or quickly in relation to the ground, and upon the nature of the surface upon which one had to land.

It was extremely important that a pupil should be taught to fly by looking at objects ahead, and not to depend upon instruments, because one could never trust mechanical things absolutely. In fact, he would like to see a training aeroplane without any instruments at all, from that point of view. On the other hand, instruments were most useful for checking one's flying. One might get careless, and develop a tendency to land too slowly—too near the stalling point—and particularly when flying an aeroplane with which one was not familiar, instruments were valuable for checking one's opinion. Navigation made instruments necessary, and not simply flying.

He was surprised that Captain Macmillan had not emphasised the great importance of the effect of inertia. A heavy machine could not change its attitude or direction of flight so quickly as could a light machine, and a pilot should always bear in mind the effect of trying to change the direction and speed of a heavy mass travelling through the air. This was a matter bordering on the scientific, but if a pilot appreciated it he would not involuntarily stall; he would realise that if he lost the lift which was being exerted on the weight of the aeroplane, it would take some time to recover flying speed and to exert that force effectively on the weight again.

It was necessary that pilots should think in at least the mildest of scientific terms. Some time ago he had occasion to write a paper on deck-landing, and in it he had used what he had thought were very mild technical terms in order to express the functions of the controls, and so on, a little more definitely than they were expressed in the training manuals. He was accused of boring the reader for whom it was intended, the deck-landing pilot, but, at the same time, he could not explain what happened under certain circumstances without referring to basic scientific facts. All pilots should know, for example, that one could not load up an aeroplane without that loading having some definite effect upon its several flying characteristics. Often the fact that the appearance of an aeroplane was similar to that of another gave the pilot the impression that it was to all intents and purposes the same aeroplane as the other, whereas in fact the alteration in the characteristics of the aeroplane by loading, or as the result of different rigging, and so on, made it an entirely different aeroplane. A pilot should take a more extended interest in the scientific aspects of flying than is usual and should not simply get into a machine, fly it and land again, and consider that that was the end of attainment as a pilot. Test pilots, of course, were in a privileged position, and were always being kept up by the designers and other scientific people to an appreciation of the scientific aspects, but the time of the ordinary service pilot was so much occupied with other service training that possibly he had not so much time or opportunity to study the scientific aspects of flying, although such study often would prove directly useful in applying the art of flying to the best advantage.

(Communicated).—Further on the question of where one should look during landing, and during full flight, he was of the opinion that the experienced pilot subconsciously selects the best objects available by which to observe his position or relative motion; close ahead to correct drift (as was pointed out by Flight-Lieut. Allen); objects in the middle distance in conjunction with objects in the far distance to determine rate of descent; and, of course, specific objects, such as another aeroplane on the ground, to determine a safe path of approach. He thought that if Captain Macmillan would reflect upon his subconscious actions during landing he will agree that an experienced pilot does not root his vision to a predetermined spot, but, like a navigator fixing his position at sea, selects those objects which best suit his purpose at the moment, and that those objects change continually throughout the approach and landing. Similarly, during full flight, when instruments are not being relied upon to keep the aeroplane on a steady path, the pilot subconsciously selects the point of reference which best suits his purpose, such as the horizon directly ahead (probably the best of all),

the next aeroplane ahead when flying in formation, and the faint image of the sun when flying in mist or through thin cloud, in preference to other points of reference which may be available.

There are two novel points which Captain Macmillan has mentioned and which appear important as landing speeds increase in an endeavour to obtain higher top speeds; (1) the fact that with certain combinations of airscrew blade-section, pitch and speed of revolution the shortest possible take-off cannot be obtained by opening the throttle fully at the beginning of the take-off, and (2) that a fast, skimming approach may enable slower contact to be made than by an approach at slow gliding speed. These two facts are, he thought, contrary to the belief of pilots generally.

Squadron Leader ENGLAND: Referring to machines with thick wing sections at Croydon, one could witness all types of aircraft landing and taking-off, and machines with thick sections, if heavily loaded, appeared to land, if anything a little faster, than those possessing wings of thin section. Captain Macmillan apparently excused the thick section being heavily loaded.

Discussing the paper generally he suggested that if anybody unfamiliar with flying had listened to the reading of Captain Macmillan's paper and the subsequent discussion, the impression gained by that individual would be that flying was a difficut, dangerous and treacherous occupation.

The text of Captain Macmillan's paper was "The Art of Flying." However, it would appear that in the main, this paper was written from a test pilot's point of view and not that of the average private owner.

Air Commodore Holt's bold statement that in America the class of aircraft which was now being sold to the "man in the street" was found too difficult to handle, was rather an assertion of what Squadron Leader Rae had already pointed out, namely, the lack of co-operation between the designer and test pilot. In this country people of all ages were learning to fly in a matter of a few hours, because the English aeroplanes were easy to manage and the system of instruction given at our flying schools was as much an art, as the art of flying.

He was unable to enlighten Captain Macmillan as to the effect of the slot in an inverted spin, but had since learned from a pilot, who had placed a slotted aircraft in an inverted spin, that the slot in such a position was of little value. That this was so, would appear to be obvious. He congratulated Captain Macmillan, however, on his very clear elucidation as to the functioning of the slot. Few people really appreciated that the automatic wing tip slot was fitted for the purpose of giving lateral stability when the aircraft was in a stalled condition.

Finally he emphasised the great importance of exercising patience in connection with flying and was surprised that Captain Macmillan had not mentioned this point in his admirable paper.

Squadron Leader PROBYN: He emphasised the importance to the pilot of a knowledge of "air lore." One could probably teach the average pupil to fly in a period of six hours, he said, if flying consisted merely of taking-off, flying round an aerodrome and landing. But before a pilot was really fit to fly across country he had much to learn; he must learn something about the air, the different kinds of country, the differences between flying in this country and abroad, and so on, if he were to have a fair chance of making a forced landing successfully. He must have some idea of wind conditions. In this connection he asked Captain Macmillan exactly what happened to a plane if, for instance, it was flying near the ground against a 30 m.p.h. wind, and suddenly came into the lee of a hangar or some other structure or obstruction. Would the aeroplane accelerate under such conditions? Finally, he said that one of the bugbears was that in high winds aeroplanes which had a big angle of incidence while on the ground were always apt to blow over. That was one of the considerations in connection with the

flying of light aircraft, and he had been hoping that perhaps the development of the autogyro would have overcome the difficulty.

Mr. W. O. MANNING: The paper had fulfilled one very important function which was not perhaps foreseen by Captain Macmillan, in that it had enabled some pilots to give vent to what was apparently a very long-outstanding grievance against the designers, the point being whether the pilot or the designer should design the aeroplane. Probably it was not a matter which should be discussed in connection with this paper, but he hoped that, inasmuch as the grievance had been ventilated, designers would pay a little more attention to the advice of pilots than apparently they had done in the past. In the early part of the paper, Captain Macmillan had referred to an aeroplane flying in four dimensions. Presumably the fourth dimension was time; if so, Captain Macmillan was getting uncommonly near to Einstein, and was perhaps varying inertia with the speed of the machine, which would add a further complication. With regard to the diagrams showing vertical flight in conjunction with the horizontal, he said he gathered that the vertical height was plotted under normal conditions—by which he meant that the air density was reduced as the height was increased—but he did not consider that was quite fair. In horizontal flight the air density could be assumed to be constant at any given altitude, and it would appear to be rather fairer to assume that the density of the air in the vertical flight was also constant; in that way a better comparison would be obtained. He agreed with the view that if a complete novice read the paper he would become a little frightened; for instance, the behaviour of a machine near the ground was described in terms which to the novice might be rather terrifying. Perhaps, therefore, Captain Macmillan would make further reference to the matter in his reply, in order to lessen the terror of any novices who might read the paper and discussion.

Flight Lieutenant ALLEN: Discussing the argument as to whether a pilot should look at a point a considerable distance ahead or only a few yards ahead when landing, he pointed out that one advantage of selecting a point not too far ahead was that by reference to that point one was better able to judge whether or not the machine was drifting sideways; if the point selected were too far ahead, one did not notice readily the drift of the machine.

Air Commodore J. A. CHAMIER (*communicated*): (1) Since Captain Macmillan talked about things which had to be done on the ground before taking-off he was sorry he did not touch on the necessity of looking over the machine. In the writer's experience, nearly all pilots—R.A.F. and otherwise—are very bad at this. There ought to be a regular routine and this can be done by a pilot in a very few minutes while his engine is warming up.

For example, starting off on the right-hand wing tip look along the leading edge of the plane for signs of warp. Hammer the struts with the hand to see that they are not bowed, cracked, or warped. Look at strut fittings and see that pins are securely in place. Hammer the plane for signs of slack wires internally. Test lift and landing wires.

Arrived at the body, look at engine while it is running to see that so far as can be seen the high tension terminals appear securely in place and valves appear to be working properly.

Look at right-hand side of undercarriage, inflation of tyres, spokes if exposed, shock absorber arrangements.

Stand back and view propeller from side to see if running smoothly; pass in front of engine and examine propeller while running from the front.

Carry on similarly along port side.

Passing to rear of plane look at aileron hinges, aileron freedom, incidence, bracing wires, flying and landing wires, and so on.

Examine engine from the left side as from the right side. Pass down fuselage, finger control wires.

Pass down to tail plane, examine kingposts, tail adjuster gear and elevators for freedom. Centralise rudder and examine fin from rear for signs of warp. Test and examine wires supporting fin and tail.

This sounds a long thing to describe, but done on a system can take hardly more than five minutes.

After climbing into the cockpit, and before feeling the controls, stand up and look along the top of the top plane. Open any door provided in the centre section and feel centre section wires. Look at instruments, examine compass for bubbles, etc.

(2) When Captain Macmillan talked about the necessity for flying without a horizon—with which he entirely agreed—it would have been of value if he had stated whether he thought that in the absence of a horizon the ear or the feel of the controls was the most valuable indication to the pilot.

(3) On the point of landings, he gathered that Captain Macmillan prefers to look well ahead rather than close down. He remembered seeing in some article a statement by a pilot that the most valuable indication of the time to flatten out was given by the flow of the ground. Until quite close to the ground the ground appears stationary and blades of grass and things can be seen clearly, but just before touching the ground appears to flow past the machine like water, and this is the point to be used for flattening out. He did not know whether Captain Macmillan had ever tried this.

(4) Finally, after landing he might have told some of those who make bad landings when to use the engine after bouncing into the air and when not to do so.

Mr. F. RADCLIFFE: There were three questions he would be glad if Captain Macmillan would deal with, and they are concerned with ground flight.

(1) Has the author any comments to make on the fitting of brake wheels to aircraft, and what is his opinion regarding the magnitude of the foot loads necessary for operating pedal brakes simultaneously, and separately, for manœuvring an aircraft on the aerodrome? Has the author any experience of landing an aircraft with both brakes on?

(2) If an aircraft had a maximum flying speed of 40 m.p.h., at what speed would the author be likely to land it and what reasons would he have for his decision? This would then give an indication of some of the rules for landing an unknown type.

(3) As it is advantageous to have a datum of some kind for focussing one's eye upon in landing in order to get the aircraft in the right attitude, has the lecturer any suggestions to make for adoption on single-seater sports planes? Or, expressed otherwise, just as one uses the spot lights on the wings of some cars for gauging one's position relative to the side of the pavement, what would supply a similar function on a small sports plane? The designer could then keep this feature in mind when laying out his projected design.

REPLY TO DISCUSSION

Dealing first with Squadron-Leader Probyn's question as to what happened to a machine when, after flying against a 30 m.p.h. head wind, it suddenly entered calm air in the lee of a structure, he said the effect is not so much one of immediate acceleration or deceleration, because the aeroplane is a vehicle subject to kinetic energy; the heavier the machine, the more likely is it to continue to travel at the same speed as previously. A very stable aeroplane is less affected than an unstable aeroplane. If an aeroplane flying in a stable condition in one air stratum encounters small local changes in the air flow or density in that particular air stratum, minor bumps result; when, however, the aeroplane flies from one stratum into a second stratum with entirely different characteristics, the aeroplane may climb or glide, and to restore normal level flight the pilot will then be required to increase or decrease his indicated air speed or else alter

his throttle setting, or use a combination of change of engine power and air speed. The reason is that, the machine having flown into different flowing air, or, it might even be, into air of different density, the wing lift is changed, with the result that the machine experiences what is generally called a bump. If the bump is maintained the change in air flow is widespread. If the initial break in the air flow is very abrupt, the bump will cause the machine to rise or fall quite suddenly. The severity of bumps depends partly upon whether the machine is flying up or down or across the wind, or whether there is any tendency to up or down currents in the initial flow and in the second air flow. Accelerations on an aeroplane due to changes in the air flow generally take this practical form of a rise or drop in its flight, owing to the fluid nature of the medium in which flight is achieved.

He illustrated the point by reference to two of his own experiences. On one occasion he was flying a machine which was rather unstable directionally. He was travelling upwards at a fairly considerable angle as fast as the machine would fly. Suddenly the machine swung to the right. The sky was absolutely clear; there was nothing to indicate change in air flow, but the machine slewed to the right, completed more than half a circle, and came out facing roughly three-quarters of the way round. At first he did not believe it, descended slightly and climbed up again towards the same piece of sky. The same thing happened. Again he repeated it with the same results. He was absolutely unable to fly through that particular piece of sky. His passenger was very sick, due to the roughness of the air at that point. The trouble was caused by a cyclone, which had a line of demarkation in the air flow so exact that he could not maintain directional flight with the forward part of the seaplane commencing to penetrate the disturbed flow of air while the tail was still in the undisturbed area. The resulting swing was so violent that he was unable to restore the directional travel of the machine. He was unable to continue the flight through the disturbed area.

On another occasion, in the Persian Gulf, he had experienced the reverse state of affairs. There was a wind with a velocity of roughly 30 m.p.h. blowing against the cliffs—and the cliffs on the Persian Gulf varied from 400 to 1,000 ft. The wind struck the cliff and was deflected upwards, and when in this air current his speed was 15 m.p.h. greater than when flying at a distance from the cliff, with the same engine throttle setting. The increase in speed was due solely to the upward tendency of the air flow, which enabled the aeroplane to obtain the requisite wing angle with the nose down and thus obtain the assistance of gravity to increase speed. If a machine hit that particular current of air suddenly the immediate effect would be, not deceleration, but an upward bump, and if the pilot checked the upward bump by means of his controls and maintained horizontal flight, speed would be increased. Sometimes the wind increased climb or speed, but sometimes it had the reverse effect. When flying one machine with a Service ceiling of 19,000 ft., he had been unable to get it through a patch of air at 16,000 ft., due to a down current in the air strata.

He was extremely sorry if his paper had conveyed the impression that he considered the pilot a down-trodden individual, or that he considered that pilots —and particularly test pilots—had a grievance against designers. He had not stated what had been attributed to him in this connection, but had certainly pointed out that the divergence between the scientific and the practical points of view in connection with flying was great. He considered this divergence was very unfortunate, because it made it increasingly difficult for the many recruits to aviation to get into touch with the technical people who had been working on aviation for many years, and to come to a mutual understanding. If there could be evolved some simplified method by which mutual understanding could be achieved, or, at least, which would enable those on the technical side to meet the non-technical, it would be to the advantage of all.

He agreed with Air-Commodore Weir that modern flying demanded too much technique. It was a good thing, of course, to know as much as possible about flying, or anything else with which one was concerned, but, apart from the purely theoretical aspects, the simpler the machines could be made the easier it would be to fly, the greater would be the number of machines in the air, and the greater the benefit to all.

Dealing further with the relations between pilots and design staffs, he said that test piloting generally occupied all one's time, all one's energy, and most of one's brain, and a test pilot had not very much time for purely technical work. On the other hand, the technician who took to flying was not likely to be able to spare enough time away from his technical work to enable him to become a pilot of the same calibre as the test pilot who did nothing but test piloting. He agreed, however, that the greater the opportunities given to technical and design staffs to learn to fly, the better, because it could only result in closer contact between the practical pilot and the purely theoretical technician.

He agreed that aerobatics occupied a high place in the art of flying, but he had not dealt with aerobatics because he had had to restrict the length of his paper reasonably; he could easily have written a paper five time as long, and would then have still more to say.

The mental-cum-practical method of flight instruction he advocated strongly. He maintained still that the average flying school—both military and civil—did not give sufficient instruction on the technical side of aircraft work. He met many pilots, both military and civil, who did not know as much as they would like to know about the theoretical side of their work, although they knew the practical side extremely well; they would dearly like to know more on the technical side, but had no means of getting to know it. With regard to the civil side as a whole, he believed that in little more than a year it would be compulsory for all pilots to have navigators' licences; yet only on the previous Saturday the Director of Civil Aviation had stated that no machinery existed in this country, outside the Royal Air Force, to enable a would-be pilot to obtain a navigator's certificate. It would be one of the first duties of the Guild of Air Pilots and Air Navigators to ensure that means were made available for the civil air pilot to learn more about the theoretical side of aviation if he wished to.

He agreed with Flight-Lieut. Jenkins that every pilot should know the different effects of spins in aeroplanes, because all machines did not come out of spins in exactly the same way. With regard to the high-lift wing, he said it appeared from the remarks made that the speakers and himself were at cross purposes, and no doubt if they discussed the matter further they would find themselves in agreement with him. If a pilot brought a high-lift wing machine down to about 2 ft. from the ground before flattening out, as suggested by Flight-Lieut. Jenkins, he would have to flatten out very rapidly when that point was reached, and the elevator moment would have to be very considerable. If Flight-Lieut. Jenkins considered that matter more closely he would realise that even when the final part of the flattening-out occurred at a height of about 2 ft., the actual change of curvature took place more gradually at a greater height, with the skilled pilot to a degree which sometimes was almost imperceptible to the novice.

With regard to the machines with thick-section wings and those with thin-section wings, he agreed with Squadron-Leader England's remarks as to the taking-off and landing being much the same, but if Squadron-Leader England considered also the relative wing surfaces of the two machines, and the loads carried, he would probably modify his views.

Flight-Lieut. Chick had misinterpreted the reference in the paper to the use of the horizon; the statement in the paper was that it should play an important part, and not that it should be disregarded altogether. In America, however, blind flying had reached perhaps a more advanced stage than it had in this

country. Lieut. Dolittle, who is one of the most noted test pilots in America, had been carrying out some wonderful fog flying, and had taken off and landed in very dense fogs; the art of blind flying was of vast importance, having regard to the prevalence of fogs, particularly in this country.

He agreed that inertia and kinetic energy were factors of importance, as pointed out by Flight-Lieut. Bryer.

In reply to Mr. Manning, he said that he did not think pilots wanted to design aeroplanes; they would much prefer to fly them—and it was much better fun than designing. As to the criticism that the diagrams were not fair, and that constant density of air during the climb should be assumed, he said that emphasised the point he had drawn attention to at the beginning of the paper—that very often the technician and the scientist wanted the pilot to do in the air something which he could not do. The pilot had to take the air as he found it; the diagrams had been prepared to show what the pilot could do, and not what might be possible theoretically but was not possible in practice.

With regard to Air Commodore Chamier's contribution I am in entire agreement with him on his first point.

With regard to the second, in the absence of a horizon instruments are vital to the pilot. I would draw attention to N.A.C.A. Technical Note No. 314 on "The Spiral Tendency in Blind Flying."

On the third point I think that there is little doubt that every pilot adopts his own peculiar methods of judging landings. I remember one war pilot who nearly always crashed when landing, due to looking over the nose of the aeroplane. When the nose came up during flattening out he lost sight of the ground, and simply sat on and waited for the crash. When we told him to look over the side after finding out his trouble he told us that he had never thought of that! I have found that pupils learning to fly usually look too close ahead when gliding in, with the result that they cannot judge the gradual change of flight path, which should be the prelude to a good alighting. Apart from the fault of looking too close I think each pilot should develop his own style.

I doubt whether point four can be conveyed adequately in print. So much depends upon the natural reactions of the particular individual. If the landing is not properly commenced in the approach, and this can generally be sensed before the final flattening out is made, I advocate making another circuit before landing.

In reply to Mr. Radcliffe I have had very considerable experience with wheel brakes of many different types on many types of aeroplanes. I have found them extremely useful for manœuvring on the ground, and I have found that they reduce landing run and make cross-wind landings safer.

Referring to para. 2, with an unknown type I always check the stalling speed and the effectiveness of all the controls at the stall whenever possible before alighting. With a strange aeroplane it is generally safer and easier to approach with slightly greater speed than one would normally use on a type with which one was thoroughly familiar. The use of engine can play a very important part in the gliding speed on the approach, but one must always be prepared to make a "dead stick" forced landing if called upon. Landings should never be allowed to become stereotyped, but should be varied frequently so that the pilot becomes thoroughly at home with all types of approaches.

Para. 3 deals with design rather than flying, and I prefer not to deal with this point in this paper.

PROCEEDINGS

THIRD MEETING, FIRST HALF, 65TH SESSION

The Third Meeting of the first half of the 65th Session of the Royal Aeronautical Society was held in the rooms of the Royal Society of Arts, John Street, Adelphi, London, W.C.2, on Thursday, November 7th, 1929. The President of the Society (Colonel the Master of Sempill) was in the Chair.

The PRESIDENT: The subject of the lecture was of great interest and of particular significance at this moment, having regard to recent fatal accidents in which machines had caught fire after crashing. The Society was fortunate indeed in having the opportunity of hearing a lecture by Dr. Dunstan, the President of the Institution of Petroleum Technologists, and Chief Chemist to the Anglo Persian Oil Company. Dr. Dunstan's great scientific work in the oil industry was so well-known that it was unnecessary to say more with regard to it on this occasion, except to draw attention to the perfect collaboration that had existed for so long with his very able colleague, Dr. Thole.

FUELS AND DOPES FOR AIRCRAFT ENGINES

BY

DR. A. E. DUNSTAN & DR. F. B. THOLE

Six years ago the present authors read a paper on "Aviation Spirit, Past, Present and Future."

At that time the subject of special interest was the possibility of finding substitutes for petroleum spirit and a variety of alternative volatile combustibles was described.

Six years ago there happened one of the periodical scares regarding a possible world-famine in petroleum and naturally the chemist at that time was anxious to find substitute fuels.

Much has happened since 1923. New fields have been discovered, some of enormous extent, new methods of prospecting have been worked out and a new technique of geophysics has been established. Far better refining methods involving much less waste are now known; cracking is going to double our supplies of gasoline and relatively enormous supplies of gasoline are now extracted from the formerly waste product, natural gas. The heavy oil engine is being developed and there is not the slightest need to trouble about a shortage of petroleum, so much so, the world views an over-production in that commodity to-day.

We have to examine to-day the criteria that the designer and user of the aero engine demand for aviation spirit. Only three out of the large number proposed at various times are of real importance. These are volatility, stability and anti-knock quality. Colour, specific gravity, low endpoint, numerical sulphur content, smell (within limits) are of little importance. These three major properties will be discussed in the sequel.

This present paper has been written with only one object and that is to emphasise the necessity for close co-operation and collaboration between the producer of the fuel and the engine designer who will make use of the fuel.

Aviation is in its infancy and in these early days it has been possible by using carefully selected crude oils to provide for the needs of the engine. This very " cream " of petroleum will no longer suffice for the aviation of the future and the designer will inevitably have to join forces with the oil chemist for a joint attack on this pressing problem. The future of gasoline supply lies in cracking and so long as the aero engine burns gasoline it will be compelled more and more to use cracked material. The bugbear of cracked gasoline is gum. This matter also is discussed later.

The question of heavy oil fuel is not discussed in this paper, which is intended to be a sequel to that to which reference has been made. Heavy oil engines and their fuel demand separate consideration. It is more than likely, however, that for some considerable time to come, light petroleum spirit will be the most important fuel and that both light and heavy liquid fuel from coal, from shale, from hydrogenation processes, from catalysis of water gas, and so forth, will play a very minor part indeed.

The question of added metallic dope is difficult, for important advantages and disadvantages are involved, but the author would suggest that a purely organic fuel—preferably hydrocarbon—for normal purposes approaches the ideal.

Requirements for racing and special " stunting " fuels are not considered in this paper, although British speed records on land, sea and in the air show that fuels can be prepared to suit engine conditions which are at present quite exceptional.

Volatility

The general range of volatility of a spirit is normally judged by the figures given by a distillation test which records the percentages distilling at intervals of 25°C. when 100 m.l. are distilled continuously from a flask under standardised conditions. Such a distillation is of course by no means a fractional separation of any precision, but experience enables one to assess the general characteristics of volatility from the figures. Thus, the percentages distilling at 50°C. and 75°C. give an indication of the amount of those particularly volatile components which afford easy starting and rapid acceleration from cold; the final boiling point shows to some extent the nature of the least readily volatile hydrocarbons present; and the loss (mainly very volatile hydrocarbons such as propane and butane) gives some information as to the presence of hydrocarbons so extremely volatile that they may be liable to create gas-locks and boiling in the carburettor at tropical temperatures or at very high altitudes.

The specifications for volatility of aviation spirit are going through the stages of modification which motor spirit underwent ten years ago. It is becoming realised that if final boiling points are kept to very low figures nothing is gained, for practically anything boiling up to 200°C. is effectively vaporised and burnt in a modern engine, while crankcase dilution is even less to be feared in an aero engine than in a car engine, because stranglers are not misused and the working temperatures are higher and more rapidly gained. On the other hand, undue restriction of the final boiling point involves a serious diminution in the quantity of spirit which can be produced from a gallon of crude petroleum and therefore a limitation of available supplies. Consequently it is not surprising to notice that modern specifications for aviation spirit have raised the final boiling point from 150°C. to 190°C., but have added a safeguarding clause in the low boiling range which ensures an ample supply of volatile components for ease of starting, but guards against such an excess of these that premature boiling would be liable to occur under strongest circumstances of pressure or temperature.

It would seem in fact that so far as volatility is concerned, aviation spirit need not differ appreciably from an average motor spirit and there are actually many cases on record of aero engines which run quite effectively on No. 1 spirits.

When maximum volumetric efficiency is demanded, however, the induced gases should be as cold as is practicable, and this may necessitate a certain additional degree of volatility in the middle range, even though the engine itself is hotter than an average motor car engine. The point has, so far as the author is aware, not been investigated and seems worthy of study.

While, however, the middle and higher range of the boiling point now is becoming of minor importance the progress of aircraft to higher elevations will in the future necessitate some attention being paid to the most volatile components. Natural gasoline (the volatile liquid obtained by stripping natural gas) is becoming more and more widely used as an ingredient of motor fuels. When freshly condensed it contains much propane and butane and is termed " wild "; in other words, it boils with extreme readiness and has an extremely high vapour pressure and is entirely unsuitable for direct use. It has to undergo a stabilising treatment which consists in boiling it under pressure to disengage and remove the propane, which otherwise would separate spontaneously and create gas-locks in the petrol system.

Theoretically, the safety of a petrol from this standpoint could be controlled by specifying a limiting vapour tension at a certain atmospheric temperature. Unfortunately, vapour pressure determinations with petrol are practically impossible to carry out with any degree of accuracy. Consequently the distillation loss is generally used as a rough indication of the absence of undue " wildness." In America a further control is given by a so-called " vapour pressure test." This is a purely arbitrary and highly unscientific determination which will however distinguish a very wild from a stable gasoline and is used mainly for judging the pressure liable to be generated in closed rail tank cars.

Volatility is, of course, linked with anti-knock value, in that in a given petrol as a rule the higher boiling components have the lower anti-knock characteristics so that a low end-point and a high proportion of hydrocarbons boiling below 100°C. tend to increase the anti-knock value. Now that so many alternative methods of conferring anti-knock qualities are known, this means of attaining it has lost much of its former importance.

Stability

Since the future of aviation involves the maintenance of supplies of fuel throughout the world, the need for the fuel to remain in storage without deterioration is self-evident. Furthermore, the fuel must maintain its initial qualities under all conditions of flying and must consequently be reasonably stable towards the extreme changes of temperature and pressure to which it may be subjected.

There are so many aspects of the " stability " problem that they may for convenience be sub-divided into Physical and Chemical Stability.

Physical Stability

The physical stability demanded of an aviation fuel is that it should remain in the tanks as a homogeneous liquid; in other words, it must not gasify, freeze or separate into layers.

Premature gasification, due to the presence of too great a proportion of " wild " hydrocarbons, has been discussed under " volatility."

Freezing is a risk which is becoming more and more serious with modern developments in flying. Petroleum spirit itself is immune from freezing—its solidification point is about -100°C. The demand for high anti-knock qualities in aviation spirit, however, enforces at the moment the addition of a large proportion of benzole, a material which when pure freezes at $+5$°C., and which even in its normal condition (containing about 25 per cent. of toluene and xylene) solidifies at a few degrees below 0°C.

The position at present is a most serious and difficult one. Modern conditions of flight demand a fuel which will not freeze at high altitudes in winter and an upper limit of about $-40°C.$ to $-50°C.$ seems to be called for. This implies that not more than 20-30 per cent. of commercial benzole can be added to a petroleum (depending on the toluene and xylene content of the " benzole ") and such a mixture does not as a rule contain enough aromatic hydrocarbons to give the anti-knock quality demanded by present-day engines.

The impasse can be avoided on a very limited scale by such methods as using toluene or xylene instead of benzole, or by employing special fractions of the petroleum spirit, or selecting exceptional spirits of abnormally high anti-knock value. All these palliatives, however, while affording a temporary solution to the problem, cannot be employed indefinitely. The demand for aviation fuel in the future will become so great that the sources of supply of the ingredients must be broadened, not artificially restricted, and it already seems inevitable that benzole must and will be replaced by an alternative anti-knock fuel which will withstand low temperatures.

Separation into layers is a problem which has only arisen in fuels containing alcohol. All the hydrocarbons are mutually miscible and when once mixed to a homogeneous liquid they will never separate. The authors have met the statement that benzole after mixing with petrol will " layer-out " on standing. This is of course purely a myth and owes its origin to the fact that if petrol is poured gently on to the surface of benzole (which is the denser of the two liquids) it will not mix at once but floats as a lighter layer. When once the two liquids have been thoroughly mixed by mechanical stirring, the blend remains homogeneous indefinitely unless cooled to its freezing point when benzene crystallises out and sinks to the bottom.

The physical stability of alcohol-benzole-petrol mixtures is a matter of importance in view of the probability of such mixtures being used for motor and aviation purposes.

Petrol and water-free alcohol are miscible in all proportions, but the mutual solubility is greatly reduced by small amounts of water and separation into two layers will occur at ordinary temperatures if the alcohol contains over 2 per cent. of water.

Since alcohol is hygroscopic it is clear that special steps must be taken to maintain homogeneity, and many substances such as benzole, amyl and butyl alcohols and phenol have been employed as " binders " with success. Since such mixtures have most of the desirable qualities of aviation fuel such as high anti-knock value, good volatility, clean and efficient combustion, low freezing point and cheapness, they will probably play an increasingly important part in aviation in the near future, especially as these mixtures are most effective at compression ratios far beyond the range of any petrol-benzole mixture.

Chemical Stability

Straight-run petroleum spirit is one of the most stable of liquids and if aviation spirit consisted solely of this the problem of chemical stability would not arise. Anti-knock requirements, however, have demanded the addition of hydrocarbons produced from coal by a high temperature cracking operation and it seems probable that in the not distant future other anti-knock hydrocarbons made from petroleum by similar and more efficient cracking processes will be called upon for improving aviation spirit. Now all hydrocarbons made by cracking contain small amounts of substances, of which the hydrocarbon indene is probably the most wide-spread and characteristic. This body on standing in contact with air becomes converted into non-volatile resins. Consequently unrefined benzole and unrefined cracked petroleum spirit develop and ultimately deposit gummy or varnish-like matter which would inevitably damage an engine by clogging the carburettor and inlet valve.

By treating the unrefined material with sulphuric acid or other suitable reagent and redistilling, these gum-forming components are removed and a stable product obtained.

Complete removal of gum-forming components is never entirely achieved and all samples of refined benzole and other cracked spirits slowly form gum on keeping. It is therefore necessary to ensure not only that such a hydrocarbon (or rather an aviation spirit containing it) is sufficiently gum free at the time of purchase, but that it will not increase in gum content beyond a certain limit (probably of the order of 20 to 40 milligrams per 100 c.cs. though research is in active progress in this connection) during the period in which it will be in storage.

No methods have yet been standardised for the determination of actual or potential gum in a motor spirit, but several important papers on this subject have been recently published (cf. Auld, Thole, Mardles and Wagner, Journ. Inst. Pet. Tech. 1929) and a great deal of attention is being directed to what is perhaps the most important problem in current petroleum research. (See also Voorhees Trans. A.P.I. Dec. 1928).

Another aspect of chemical stability arises in connection with the storage of doped fuels. Very small amounts of certain chemicals such as lead ethyl, iron carbonyl, aniline, ethyl iodide, etc., are known to have powerful anti-knock qualities. While some of these are stable others are liable to decompose or oxidise on keeping. Since the amount of the dope is so small a slight amount of decomposition will have a magnified effect on the anti-knock quality and consequently doped fuels must be subject to very careful control tests, especially where an unstable dope is concerned.

Anti-Knock Value

The tendency of a fuel to " detonate," " pink," or " knock " (to use terms which everyone understands but cannot accurately define) is influenced by a number of factors, the chief of which are:—

(1) The design of the engine. This includes such factors as compression ratio, shape of combustion head, bore, stroke and number of cylinders, turbulence, position and number of sparking plugs, and cooling—all of which have a profound influence on the tendency to " pinking."

(2) The chemical nature of the constituents of the fuel.

(3) The external atmospheric conditions, especially temperature, pressure and humidity. The effects of these are not yet known with complete accuracy, but much research is in progress.

Engine Design

Early recognition of the fact that increased efficiency is attained by increasing compression ratio has led during the past few years to progressive increase in this factor both in car and aero engines, until a point has been reached where the limitations of the petrols available forbid any further increase. In aero engines in fact compressions are in general so high that no straight run spirits can be used and special blends (which are necessarily limited in quantity and relatively expensive) are necessary. It is now time that more attention was paid by the Research Departments of the engine manufacturers to the other factors enumerated above, for the authors are convinced that by suitable selection of the best degree of turbulence, the best bore-stroke ratio, the best positions for sparking plugs, etc., it will be possible to use straight petrol at high compression ratios without pinking or, conversely, to use the special blends at much higher compression ratios than are now in vogue.

The tendency hitherto has been for the engine manufacturer to produce his engine and then demand a fuel suitable for it. Real progress can only be achieved by closer co-operation between the engine designers and the fuel producers, so

that the knowledge and experience of both can be utilised to the common advantage.

Chemical Nature of the Fuel

The detonating qualities of the different types of hydrocarbons are so well-known that the briefest reference will suffice. Broadly speaking, paraffin hydrocarbons detonate most readily, naphthenes and olefines at a higher compression ratio, while aromatic hydrocarbons preignite before they detonate. There are, however, many exceptions to this crude generalisation. Thus the lower paraffins (butane and pentane) have strongly marked anti-knock qualities, while among the higher members of this series branches chain isomers (for example iso-octane) have similar properties. Naphthenes and olefines also vary considerably according to their atomic structure. It follows, therefore, that methods which assess anti-knock value on an analytical grouping into "paraffin," "naphthene" and "aromatic" content are entirely unreliable and it is now universally agreed that anti-knock valuation can only be made by means of a suitable engine test.

Up to the present, anti-knock quality has been obtained by adding coal-tar benzole to a petroleum spirit. Naturally, the higher the anti-knock value of the petrol the less benzole is required to confer a required standard of anti-knock. This means less risk of freezing and usually less cost, but at the expense of limiting the available supply. There is also a limit to the amount of benzole that can be added, since very rich benzole mixtures at high ratios preignite and therefore are liable to damage the engine. Recent developments in petroleum technology have offered a new solution, in that cracked spirit (produced by a variety of modern processes from heavy petroleum residues) has a relatively high anti-knock value depending on the cracking stock used, the temperature of cracking and the nature of the refining process used. Although cracked petroleum spirit is very widely used for motor fuel its use has so far been banned for aviation spirit because, if inadequately refined, it is liable to form resinous products on prolonged storage. This difficulty is now near solution and we may expect to find this new source of anti-knock fuel used in aviation spirit as soon as the authorities are satisfied as to its keeping qualities.

In the meantime alternative methods of reducing detonation tendencies are known. The value of alcohol has already been referred to and petrol-benzole-alcohol mixtures have been used in engines at a compression ratio of even 12 to 1 with great success.

Dopes, such as lead ethyl and iron carbonyl, have also been used with success, though they have certain admitted disadvantages as well. One disadvantage is that the resultant effect becomes less and less as the dose becomes heavier.

Evaluation of Anti-Knock Quality

Ever since the importance of anti-knock quality was appreciated, a method has been sought whereby this quality could be determined with accuracy and expressed numerically.

The first method to be developed arose from the work of Ricardo, who designed an engine with a variable compression head which was calibrated and could be adjusted while the engine was running. Ricardo's method was to run the engine under certain defined conditions of speed, load, temperature, ignition setting, air-fuel ratio, etc., and to record the compression ratio at which the power curve ceased to rise. This he termed the Highest Useful Compression Ratio (H.U.C.R.) of the spirit. It may coincide with heavy, moderate or light pinking according to the size and type of the engine.

All the pioneer work on anti-knock valuation was done by this investigator; his results have been of the greatest value and his work has received world-wide recognition.

The H.U.C.R. method, however, suffers from the great objection that it is a purely arbitrary figure which depends entirely on the details of design of the engine and the running conditions. If the volume of the cylinder, the position of the sparking plug, or any of the running conditions are changed an entirely new value for the H.U.C.R. of the spirit is obtained. For example, the H.U.C.R. of a well-known petrol is 4.7 in Ricardo's E.35 engine, 6.3 in his E.5 engine, 6.8 in an Armstrong experimental engine and 4.4 in a Thornycroft experimental engine, each ratio corresponding with what may be termed " moderately heavy pinking." Consequently such a method of expression result could only be standardised if all those who wished to make tests possessed replicas of Ricardo's engine and operated it under identical condition—an impracticable suggestion.

An alternative method, first proposed by Graham Edgar and now widely adopted, as it is fundamentally more sound, is to match the fuel in an experimental engine against blends of two standard hydrocarbons A and B of known purity, one of these being pro-knock and the other anti-knock, so that mixtures of them cover the whole of the required range.

The value of a fuel is then expressed numerically by stating that it matches a specified percentage blend of A with B. The great advantage of this method is that it is practically independent of the engine used, and the running conditions (provided certain essentials are conformed with) and as the hydrocarbons can be obtained (at present, however, with some difficulty) in all parts of the world, operators in all countries can express their results in comparable terms.

The choice of hydrocarbons is difficult and is still under discussion. Edgar proposed normal heptane as the pro-knock and 2.2'4 trimethyl-pentane (an iso-octane) as the anti-knock hydrocarbon. In view of the cost and relative difficulty of synthesising the latter hydrocarbon the authors have suggested and adopted pure crystallised benzene, which is cheap, as a preferable alternative. Whatever may be the hydrocarbons finally chosen as a result of experience and collaboration it is evident that they must be chemical entities, the purity and uniformity of which can be checked and guaranteed. No fraction cut from petroleum can possibly conform to this requirement, though petroleum fractions can be and are used as sub-standards for ordinary testing, provided they themselves have been calibrated against the fundamental standard hydrocarbons.

The form of engine developed by the authors after several years of experimenting has been fully described recently (Thole and Stansfield, Journ. Ind. Eng. Chem. 1929). It consists of a small variable compression engine coupled with a dynamometer and provided with an improved form of the Midgley Bouncing Pin, which is much more sensitive than the human ear, and eliminates the personal factor in determining the degree of " pinking." The technique and certain essential conditions are detailed in the paper referred to and the method of testing has been brought to the degree of accuracy that the effect of 1 per cent. of benzene added to an ordinary motor spirit (equivalent to a change of 0.015 in compression ratio) can be readily measured.

The importance of standardising a procedure for testing fuels and expressing their anti-knock value is so widely recognised that steps are being taken by an authoritative committee in America to develop such a procedure and their work is being closely followed by collaborators in this country, where intensive research is also in progress. While very many criteria can be asked for in aviation spirit, there are three only which are of really fundamental importance in assessing the suitability of the material for aviation purposes. Provided that these are satisfactory there must be no reluctance to draw supplies of fuel from a much wider range of sources than merely petroleum spirit and benzole. Otherwise this fast growing and vital industry will suffer from all the effects of a starvation diet and may become permanently stunted in development. Furthermore, it is imperative that much close collaboration and mutual interchange of opinions and assistance is necessary between the producer of the fuel and the designer of the engine if real and rapid progress is to be achieved.

Discussion

The President: He expressed his thanks to Dr. Dunstan and Dr. Thole—who had been collaborating in this work for over twenty years—for their lecture, and, also, for having placed in their true perspective questions as to the colour, smell, and so on, of aviation spirit, to which too much attention was sometimes paid. It was re-assuring to hear from such authorities as Dr. Dunstan and Dr. Thole that one need have no fear as to the petroleum supplies of the world running out within a period of twenty years or so, and their remarks as to the limitations of obtaining fuels from such a source as British coal, were very interesting. Referring to Dr. Dunstan's views on cracking spirit he asked if this oft-debated question could not be elaborated on more fully, possibly with the help of the Air Ministry technical representatives. He commented on the fact that Dr. Dunstan had not said much about the compression ignition engine, but one could hardly divorce the consideration of this type, and of the Hesselman type of engine, from a discussion on aircraft engine fuels. It had been pointed out that the result of the cracking process would be approximately to double the yield of petrol. That would obviously be a very desirable thing if the design situation were to remain as it is to-day, but if, on the other hand, one was to use the compression ignition engine, or an engine working on the Hesselman principle, the economic balance of the situation would be altered, as he believed Dr. Dunstan would be the first to admit. Dr. Dunstan had rather doubted the practicability of standardising a test engine, but he would be the first to admit the necessity of standardisation of some kind as, at the present moment, it was almost impossible to appreciate the significance of results obtained in foreign countries. The problem of providing a fuel other than petrol was important, not only from the point of view of safety, but also from the point of view of economy in consumption and in first cost. He asked Dr. Dunstan if he could give an idea as to the lightest fuel that could be obtained for a long distance record-breaking flight, for which something like 1,000 gallons would be carried and in which weight consideration was of supreme importance. In congratulating Dr. Dunstan and Dr. Thole upon the production of their test engine, he acknowledged that excellent work had been done with the Ricardo engine, but in view of the fact that results depended entirely on aural observation, he thought it was hardly a type that could be perpetuated.

Dr. Thole (who was invited by the President to discuss those parts of the work described in the paper with which he had been specially concerned): The paper was written partly to put forward the views of Dr. Dunstan and himself as to the trend of requirements in regard to aviation spirit, but principally with the object of provoking a good discussion, because frank discussion was of extreme value to those concerned with the petroleum and the engine industries. In emphasising the plea for closer co-operation between engine designers and the petroleum technologists, he said there had been too great a tendency in the past for engine designers to modify engines without considering the repercussion of such changes on the fuel problem and therefore to leave at times absolutely impossible tasks to the producers of spirits. By proper co-operation, the problems of both could be rendered very much easier, and he was gratified to note that recently there had been more and more a tendency to co-operate—a tendency which he hoped would grow.

Dr. Thole then went on to describe, and to illustrate by means of lantern slides, the engine which his Research Department has designed for the purpose of testing the detonating qualities of spirit. The main ideas in their minds when developing that engine, he said, were that it should be cheap, easy to maintain in good condition, sensitive and accurate. As a result they had produced an engine, the cost of which represented a mere fraction of the cost of earlier engines which had been used for such purposes. It was simple and robust in

construction; a full description of it, together with drawings, were contained in a paper which Mr. Stansfield and himself had published a few months ago (Journ. Ind. Eng. Chem., 1929, p. 98). They had developed one or two special accessories which increased the accuracy of observation to a very high degree, and he believed it now represented the most accurate and simple detonation-measuring engine of its type. Parallel work was being carried out in America, and he was glad to be able to say that there was very close co-operation between the workers in that country and this.

The engine which he and his co-workers had developed was a simple single-cylinder engine of 370 c.c., with controls to all the essential points, namely, the fuel feed, air/fuel ratio, speed, temperature, and so on. It was constructed with a variable compression head operated by a hand-wheel, so that in the engine one could test any spirit, whether of low or high anti-knock value. The range of compression ratio of the engine went up to about 8/1, and the accuracy of results had been increased greatly by the use of an improved type of Midgeley bouncing pin. This was a mechanical method of indicating the degree of detonation. It was used to deflect an ammeter and also to operate the usual voltameter which measured the amount of gas developed, and therefore, this engine was, as far as could possibly be devised, independent of the human element. This was one of the most important advantages of it. One had not to listen for pinking, so that a deaf person could work it as well as a normal person. Everything was recorded on instruments.

Dr. Thole showed photographs of the engine, together with a drawing of it, the latter showing clearly the design of the bouncing pin mechanism and of the variable compression head. Another illustration was that of a type of flow-meter and fuel feed system which had been developed for use in the engine. This system automatically eliminated the float chamber and supplied the fuel under a constant head to a needle-regulated spraying nozzle by means of which the air-fuel ratio and the actual feed could be controlled and recorded. Experience had proved that accurate and reproducible results could be attained with certainty only when fine control of all the variables influencing the running of the engine was achieved and the personal equation eliminated by recording the behaviour of the engine by electrical or mechanical means.

Mr. Pye (Deputy Director of Research, Air Ministry): It was only the prosperous concerns like the oil companies that found themselves in a position to carry on research. With regard to detonation, Dr. Dunstan had rightly emphasised the desirability for co-operation between oil producers and engine designers, but that did not really carry them very far. However much co-operation there might be between oil producers and engine designers, it would always be up to the fuel producers to produce a better fuel, because the engine designers would always want to increase the compression ratio, and no amount of co-operation would get rid of this bugbear of detonation. Co-operation was only a palliative, and the producers would always be faced with the problem of producing a better, and still better, fuel from the anti-detonating point of view. He was rather surprised that Dr. Dunstan appeared to hold the view that our salvation in the future would lie in the use of cracked spirits. Dr. Dunstan had been rather careful to say that " purified " cracked spirits were excellent from the anti-detonation point of view, and Mr. Pye asked him if he could at present produce cracked spirits sufficiently purified to be acceptable for use, at a price which would enable them to compete with other forms of aviation spirit. He suspected that behind the word " purified " there was much which lay hidden. Much satisfaction was to be derived from the news as to co-operation in regard to standardisation. An immense step forward would have been taken if all the fuel producers in this country could agree, not only upon a standard fuel, but also upon a standard method of comparing other fuels with the standard; and if they could include producers on the other side of the Atlantic, so much the better.

The history of dopes was almost as romantic as that of detonation. There was a story that during the war it was thought that, as lead tetra ethyl was highly " indigestible " in the human frame, it might also be bad for the engines of German submarines, and someone had suggested putting it into fuel which it was known was going to Germany, the idea being that it might hamper the operations of the U boats. He would not answer for the truth of the story, but the discovery that lead tetra ethyl was far the best anti-detonating dope was to some extent a romantic fluke, and even more remarkable was the fact that, in spite of the work done by the most skilful and experienced chemists and engineers on both sides of the Atlantic since, nothing really comparable in regard to anti-detonating properties had been discovered. It remained for Dr. Dunstan and his collaborators, therefore, to pursue this matter further and to try to discover something better in the way of a true dope, *i.e.*, something that could be added in very small proportions to the fuel. He hoped that when they discovered a dope which was more satisfactory than lead tetra ethyl from the point of view of the engine, it would be one that was non-poisonous, because one did not want more poison scares, committees of inquiry, and the spending of more time and public money to prove that if one spilled a little ethyl petrol on one's hand one need not rush to the doctor or the hospital. He asked for Dr. Dunstan's views as to the possibilities of discovering improved dopes as distinct from the development of anti-knock fuels through either cracking or blending processes.

Mr. Foord: Commenting upon the necessity for co-operation between engine designers and fuel producers, and Mr. Pye's suggestion that the solution of the problem lay mainly with the fuel producers, he thought that a great deal could be done in the direction of improving engine design. Questions of distribution, induction manifold and combustion chamber design, were of the utmost importance. He expressed disappointment that Dr. Dunstan had laid very little stress on the possibilities of using fuels produced at home by the low-temperature carbonisation process. Whilst the amount that could be produced at the moment from the aviation point of view was negligible, surely within the next six years considerable improvements would be effected, as was the experience of the last six years already referred to by the lecturer. This was a matter of national importance which should be tackled, and steps should be taken to effect improvements. Dr. Dunstan had referred to volatility, and had said that we should do all we could to see that the fuel entered the cylinder at a low temperature. Undoubtedly that was a thing to aim at, but there were almost insuperable objections. Unfortunately, there was such a problem as that of distribution in aircraft engines, and it was a real problem, apt to be more vital in an aero engine than in a motor car engine, particularly as an aero engine had to operate at heights of 20,000 or even 30,000ft. It was necessary to ensure by artificial heating on the induction and carburation systems that the distribution was such as to make for sweet running and this is all against ensuring that the fuel entered the cylinder at a low temperature. That was a problem in connection with which the co-operation of the aircraft engine designer and fuel producer was essential.

The importance of finding a substitute for benzole could not be exaggerated. Crashes had occurred as the result of the freezing of the benzole compound, and the sooner we could find an equivalent by means of which the freezing difficulty could be overcome, the better. With regard to alternative fuels, and the suggested use of alcohol-benzole-petrol mixtures, he pointed out that the weight factor was important in the case of aircraft, and the fuel consumption, on a weight basis, was apt to be more in the case of the alcohol fuels than of the ordinary straight petroleum products primarily because of the lower calorific value of such fuels. That disadvantage could be overcome to a great extent by increasing the compression ratio, but one could not get it all back in that way, there is a practical limit to the increase in compression ratio. With regard to stability, and particularly chemical stability, he drew attention to the effect of

fuels on different metals, especially of alcohol blends of fuels and doped fuels. They were confronted continually with the problem of corrosion in the aircraft engine, even when using benzole mixtures, and when dopes and other anti-knock devices were used the difficulties in this respect were enhanced. Referring to cracked spirit, he said that until such a spirit was produced with a low gum content they were not justified in carrying out long-continued tests. In mitigation of that, however, he said it was not proposed to use straight cracked spirit, however high its anti-knock value. A proportion of, say, 20 to 30 per cent. would help, just as a proportion of benzole was used for anti-knock purposes, and probably blends of that order would not be so disadvantageous from a stability point of view as a plain cracked spirit. The storage problem was an all-important one for big commercial aircraft organisations. He was given to understand that cracked spirits could be guaranteed not to form excessive amounts of gum when stored for periods up to six months; that was all to the good, but not good enough. The Royal Air Force had to store fuels in all parts of the world, sometimes under very bad conditions, such as high temperature conditions, and so on, and it was absolutely necessary that there should be no gum formation. He emphasised the importance of the point raised by Mr. Pye with regard to a standard of reference as to detonation. At the Air Ministry they had tried to tackle that problem; it was a very difficult one, and it all boiled down to standardisation of the reference fuels. A reference fuel was required which would be cheap, easily reproduced and which would be constant in anti-knock value under all operating conditions.

Wing-Commander HYNES: Commenting on Dr. Dunstan's reference to the raising of the end points, or, in other words, reducing volatility, he emphasised that this might lead to further losses due to difficulties in connection with distribution. He was surprised that Dr. Dunstan was so optimistic with regard to the production of a dope-free spirit, and he asked how soon it was likely to be produced, and whether laboratory results which justified that optimism had been obtained. If there were possibilities of producing in the near future a dope-free spirit which would give the same performance as a spirit in which lead tetra ethyl was used, that was wonderful news. He was interested in the problem of inspection, and incidentally, the problem of the inspection of petrol was one of the biggest bogies he had had to deal with; the tendency towards regarding anti-knock value as a prime consideration was one which he welcomed very much, because it would undoubtedly simplify the technique of testing spirit. There was the difficulty of standardising the actual method of determining it, but there is now on the market quite a cheap engine which appeared to do the job very well. Its application was based on the matching of two reference fuels. He did not know whether the same relative results were obtained when the fuels were tested on different types of engine. Prior to the use of such an engine the only test had been a most laborious one, involving the determination of aromatics and that sort of thing, and when that had been done it was doubtful whether the result obtained was really useful. With regard to co-operation between fuel producers and engine designers, he pointed out that the latter were faced with many mechanical problems. An attitude of give and take was necessary, and it was a mistake to imagine that if the oil producers considered that the use of a very complicated head, for example, was desirable, the engine designers could go very far towards meeting that requirement.

Mr. H. B. TAYLOR: Great stress had been laid on the extreme accuracy of the test observations when the Armstrong-Whitworth engine was used, but it appeared to him that the crankshaft in that engine was mounted in plain bearings; whilst this might be excellent for the determination of the properties of a lubricating oil, it did not appear to be ideal for testing fuels. He believed it could be accepted that the higher the friction losses the less accurate were the results, and although it had no effect on detonation determinations, it would lead to

inaccuracies in the determination of specific consumption of different fuels. That, however, was a minor point. Referring to the possibilities of the use of the compression ignition engine, he said it had been suggested to him that fire risk did not matter, but he was not in sympathy with that view. It had also been asserted by the same people that economy would be the only justification for the use of the compression ignition engine. Some time ago the representative of an oil company had told him that the compression ignition engine for road transport would never materialise, because, should its advent threaten to put the petrol engine out of business, the oil companies would have no use for the lighter fractions. The price of petrol would then be so reduced that it would not be worth while using the compression ignition engine. He asked what Dr. Dunstan had to say about that. He was disappointed that dopes had not been dealt with more fully in the paper, because he had hoped to hear of the development of something which would replace lead tetra ethyl and which possibly would give even better results. He had been closely associated with a good deal of work in this country in connection with lead, and even to-day it was not all that it might be from the point of view of its effect upon the engine. When the compression ignition engine came to the fore we might need another form of dope, *i.e.*, a dope in the form of a fuel accelerator, which would accelerate the rate of combustion or, rather, reduce the lag between injection and ignition. He asked if Dr. Dunstan had any information on substances which might be used for that purpose, and what their effects were likely to be.

Mr. Evans: For 50 years internal combustion engine designers had been troubled with detonation problems. In the heavier and older type they had found that the only method of eliminating it was by the method of the Diesel engine. In connection with the development of the aviation engine the designers had been helped by the oil producers, but it seemed still that the task before the designers and fuel producers was a very heavy one, and he suggested that the ultimate answer to the problem would be again found in the Diesel engine method. Commenting on the suggestion that had been made to Mr. Taylor, that, if the compression ignition engine were introduced, the price of petrol would fall to such a level that there would be no advantage in using heavy oil in its place, Mr. Evans said that he had been told exactly the opposite. On more than one occasion he had been told that the moment the London General Omnibus Company's 'buses began to run on heavy fuel, or the moment the R.A.F. used heavy oil engines, petroleum producers would immediately increase their prices, perhaps to double the present prices. His answer to that was that one good-sized motor ship consumed sufficient fuel in a day to keep the average hard-worked 'bus going for three years.

Mr. Bramson: The problem of detonation always gave him a certain amount of mental distress, because, although it was of immense importance, it was difficult to realise quite what it consisted of. He did not imply that one needed to understand it so fundamentally as to make it necessary to study atomic questions, but one did like to visualise the phenomenon to some extent. He gathered that detonation was of importance because it gave rise to loss of power; there was less power than there should be, having regard to the compression ratio. Was that loss of power due to the fact that, owing to the very high reaction velocity, such high temperatures were developed that the gas constants changed, as he believed they did at extremely high temperatures and pressures; or did the high reaction velocities produce such intense turbulence that power was lost as a result? He also asked whether a phenomenon similar to that of detonation in petrol engines occurred in compression ignition engines. One never heard about it, but he could not see why not, in view of the fact that there were higher temperatures and pressures associated with the Diesel cycle than in the ordinary Otto cycle. He was obsessed with the

idea of reducing fire risk. That was not a "fear complex," because one does not think about such things when actually flying, but if one could picture the condition of people perishing by fire after a crash, one could not help perhaps even exaggerating the importance of avoiding fire. It seemed to him that the compression ignition engine must come, provided it did in fact decrease materially the fire risk. He asked if Dr. Dunstan had facts and figures bearing on the relation between the flashpoint or boiling point of the fuel and the fire danger, because there seemed to be controversy on the subject. Some people held that when fire occurred on crash, fabric or wood soaked with heavy oil first caught fire, which fire in turn ignited the petrol vapours which had been formed in the meantime. Finally, he asked if Dr. Dunstan and his collaborators had considered, in connection with their work on detonation, the use of the extremely sensitive and accurate maximum pressure indicator (a component part of the "Farnborough" indicator, which he believed was developed by Mr. Wood, of Farnborough), for it gave an indication even of incipient detonation long before one could discover it by ordinary means.

Mr. STANSFIELD (Engine Test Section of the Anglo-Persian Research Department, Sunbury-on-Thames): Commenting upon Mr. Pye's suggestion that, although the engine designer might improve his engine, he would still want a better fuel so that he could improve it further, said that would be true for special purposes, but he asked if it would be possible to produce at a reasonable price and weight an engine for ordinary aviation purposes at a ratio much higher than is used at present. Would it be possible, for instance, to improve on a ratio of 6:1 or 7:1 without adding materially to the cost of the machine? Might it not be possible, by paying further attention to engine design, to avoid the necessity for using only the "cream" of the spirit? With regard to the effect of "ethyl," he said it was an amazing dope, and particularly useful when the initial value of the spirit to which it was added was already high, but as the supplies of the spirit required became greater, possibly with corresponding drops in anti-knock value, it would be necessary to add more "ethyl," unless a cracked spirit could be introduced as well. The effectiveness of "ethyl" fell rapidly in proportion as the concentration was increased, while the troubles connected with its use were intensified with concentration. Even now it is used frequently for high ratio engines with the addition of benzole. With regard to the distribution problem, surely that was primarily one of engine design. If the application of a single-cylinder engine design to a multi-cylinder type reduced the performance by 10 per cent., it seemed to him that the distribution system required considerably more attention from the engine design point of view, and if a reasonable proportion of the 10 per cent. loss could be recovered, it would also help the oil interests to increase the middle fractions of the spirit with beneficial results both as regards anti-knock and available supplies.

As to the use of reference fuels in the test engines, he said that experiments on three types of engine had been made in his laboratory, and they had been able to make comparisions with tests on different types of engines in other laboratories. If the reference fuels were identical, and if the technique were suitable, then over ordinary temperature ranges the maximum difference between the results obtained by two operators working on different engines was of the order of 2 or 3 per cent. of benzene; he believed it could be reduced below that. He was not sure about the use of ethyl, however, because that was a peculiar substance, and there might be changes at high temperatures. This question needed further investigation. As to the criticism that the crankshaft of the Armstrong engine was mounted on plain bearings, he said the engine was designed primarily as an anti-knock testing machine. It was designed because a cheap engine with a variable compression head was needed, and one which could be sent out for use by comparatively unskilled operators. The lubrication system was entirely by splash; there was a copious supply, and bearing pressures were extremely

low. Over a series of tests made a few weeks ago to determine power outputs and fuel consumptions, the variation between repeat tests extending over three hours continuous running was only in the ratio 181 to 182, *i.e.*, only about 0.5 per cent. change. Those results compared very favourably with the results from an elaborate ball-bearing design.

He had used a modified form of the Farnborough indicator as a means of detecting incipient detonation, and had obtained some interesting figures indicating very high local pressures. Although the bouncing pin instrument used with the variable compression head would not detect the very beginnings of detonation, it gave accurate comparisons which agreed with comparisons made by other methods with the detonation not so heavy.

A point with regard to engine design and anti-knock rating to which his attention had been drawn recently was the risk of confusion between pre-ignition and pinking. It was possible to select certain fuels which could be blended with pinking fuels. These selected fuels were anti-knock in themselves. With small concentrations the anti-knock effect was linear with concentration; as the concentration was increased, the anti-knock effect increased, but less rapidly, until a maximum was reached, and then, with further increase of the anti-knock fuels, the ratio with which it was possible to run the engine decreased. The low concentration blends were pinking but non-pre-igniting, the high concentration blends were non-pinking but pre-igniting. Pinking and pre-ignition could easily be distinguished, however, for if the speed were reduced, and the spirit were a pinking blend, pinking increased; if speed were increased, the pinking died out. If the blend were pre-igniting, increase of speed made the knocking heavier, but with decrease of speed it died out. This suggested that in certain cases of trouble with high-compression engines an effect which had been attributed to a low anti-knock value of the fuel was really a pre-ignition effect which could be cured by suitable engine alteration, the pre-ignition effect being due probably to a local hot-spot, whereas pinking is a function of the general temperature distribution.

Reply to Discussion

Dr. Dunstan, replying to the discussion, said that perhaps the title of " Fuels and Dopes for Aircraft Engines " had been rather thrust upon him, and if he had had time to contemplate it he would have dropped " dopes " out. Perhaps there was a moral in that remark.

Commenting on the President's suggestion that the possibility of using the Diesel type of engine might upset the economic balance between light and heavy fuels, he pointed out that the petroleum chemist had made light spirit from heavy oil, and there was no reason why he should not reverse the process and turn the spirit into heavy oil for the ignition compression engine.

As to Mr. Pye's suggestion that a purified cracked spirit must be produced to satisfy the Ministry, he might ask what degree of purity was wanted.

Replying to Mr. Foord's remarks as to obtaining gasoline from coal treated by the low-temperature carbonisation process, he said at present there are a few plants carbonising coal to the extent of a few hundred tons per day, and making, he supposed, about 10 per cent. of tar from those coals. On the other hand, the imports of gasoline of all sorts amounted to 800,000,000 gallons per annum. He agreed with Mr. Foord entirely, however, with regard to the importance of replacing benzole, which might have other uses, but he did not see how, short of the wide application of metallic dopes, one was going to replace benzole without employing cracked spirits. The cracked spirit of to-day and of yesterday were very different materials, and he had been referring in his paper to cracked spirits whose anti-knock value was possibly superior to that of benzole. As Wing-Commander Hynes had suggested, the anti-knock fuel which was superior to benzole would probably be used in a blend, and conceivably, therefore, its stability

would be affected by the blending. It was certainly a fact that if a cracked spirit with a gum test of 30 were blended in a 50/50 concentration with a straight spirit having a gum test of 0, the gum test of the blend would be below the arithmetical mean of the two components.

Dealing with the question as to whether, if a series of reference fuels were tested on different engines in different places, the results would be accurate and reproducible, he said that intensive researches had been carried out in three research laboratories in this country, using three different engines, each laboratory using the same reference fuels, and each laboratory had placed nine commercial gasolines amazingly accurately in order. Given a definite reference fuel, the figures were reproducible, irrespective of the engine.

Mr. Taylor had tried to draw him on economics and the question of low prices, but he was not going to be drawn into such a discussion. As to the extended use of the Diesel engine effecting an alteration in the balance of commodities, he said it was conceivable, and probably feasible, so to control the refining process as to produce from a given petroleum ample quantities of any desired fraction.

He did not propose to discuss the whole theory of detonation, but he pointed out that the most recent work by Prof. Wheeler had shown pretty clearly, and photographically, that in a fuel in which detonation was proceeding there was always a phenomenon called "after burning." It looked as though, in a detonating fuel, the total calories were not used, but that some of the calories were liberated in a subsequent phenomenon—after burning—which would explain the loss of power. That theory, he believed, had not received the attention it deserved.

With regard to flashpoint and fire risk, obviously the higher the flashpoint of a given oil the less the fire risk, generally speaking, though there were local conditions in which that was not quite true. For example, in the Anglo-Persian Company's refineries in Persia, where the atmospheric temperature was very high, fires were usually associated with kerosene, merely because gasoline at that particular temperature made a mixture with the air too rich to explode. There might be local conditions in which, due to the atmosphere, a high flash fuel would be more dangerous than a low flash fuel, but broadly speaking, with increasing flashpoint he would expect increasing safety.

AIR PHOTOGRAPHY SURVEYS

BY

J. DURWARD, F.R.G.S., F.R.P.S., A.F.R.Ae.S.

Air Photography and its serious application to map-making may be traced to the Great War. It was at this period that grave consideration had to be given to Air Photography as a method of producing maps.

In all the theatres of war, which included France, Palestine, Salonica, and Mesopotamia (or Iraq as this country is now known), extensive operations were carried out in Air Photography, and the photographs used for the amplification of existing maps, and in many cases to the compilation of new maps.

Since the War great strides have been made in this method of mapping, in Europe, America, Canada, and in the East.

During the years 1918 to 1920, the writer was in control of Aircraft Photography in Iraq and Persia, and in close touch with Air Photo Mapping. Maps were required by the Civil Administration in these countries. Air Photographs were taken by the Royal Air Force, and supplied to the ground surveyor, who compiled maps, after fixing ground co-ordinate control points on which the photo mosaics were adjusted to insure accuracy of scale, etc.

In 1919, the writer assisted with experiments which were made at Air Photo Cadastral Mapping in Iraq. Maps were compiled to a scale of 72in. to 1 mile, and were used for the registration of land and revenue purposes. Air Photographs were taken to a scale of 8 to 12in. to 1 mile, over the towns to be mapped, and from the negatives of these photographs enlargements were made to a scale of 24 to 36in. to 1 mile, and the photo sheets mosaiced, after which these mosaics were rephotographed in sections, and from the photo negatives still further enlarged to the scale of map required, namely, 72in. to 1 mile. The enlarged photo sheets were then issued to the Tapu Department, Bagdad, who in turn inked up with water-proof ink on the enlargements all details necessary for the maps. This work entailed taking the photo enlargement sheets into the field, *i.e.*, the various towns and villages which had been photographed, in order that the photographs might be marked showing property boundaries, and such other information as might be required by the Tapu Department.

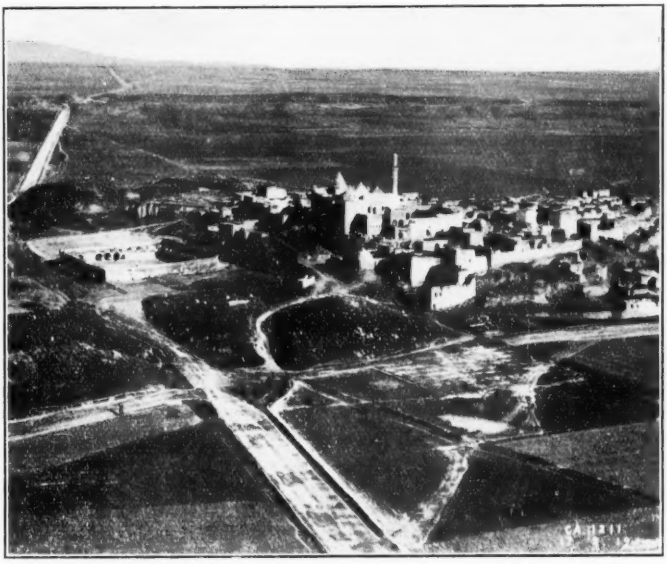
On completion of this work, the photographic image was bleached, leaving only the inked-up detail on the surface of the paper. The next procedure was to print the fair map, which was done by the Vandyke or similar process by the Survey Party M.E.F. It might be added here, that in these early days, Air Photo Cadastral Maps could not be considered as extraordinarily accurate, in view of the fact that for such large scale mapping, little or no elaborate ground control was used as a check on the accuracy of the air photos, and yet at the time the results seemed to be considered fairly satisfactory to the Tapu Department, and probably gave most of the information required, besides effecting a greater saving of time and cost than if the maps had been produced by the ordinary ground survey methods alone.

In recent years and in the writer's experience a considerable amount of Air Photography for small scale mapping has been carried out on the Frontier of India, both in oblique and vertical photography over the mountainous country with fair success, also, experimental work and commercial Air Photography Mapping has been in progress, and carried out by various nationalities in different

parts of the world, particularly in Europe, America and in our own Dominions overseas in the East and West.

In 1924, forest surveys were carried out in Burma, of forest and mangrove swamp areas, on the Irrawaddy Delta (approximately 1,400 square miles were surveyed by means of Air Photographs); in this connection the writer was responsible for the photographic results. As much has already been written in the past on this particular survey it seems unnecessary now to go into further details.

Between 1924 and up-to-date all manner of air surveys have been attempted and in most cases successfully completed. This includes surveys of forest areas, land settlement and town surveys. The particular type of air survey to which the writer has recently been closely allied, is that of Land Settlement Air Photo Cadastral Mapping in India, and in the compilation of Land Settlement Revenue Maps to a scale of 16in. to 1 mile, over comparatively flat country. A brief description is given later of the methods employed and the routine followed in the production of these maps.



Nineveh, oblique photograph.

The Object of an Air Photography Survey

The object of an air photo survey is to produce through the medium of photographs taken from aircraft a topographical or Cadastral Map similar to that compiled by ordinary ground survey methods.

In order that this may be accurately accomplished and to assist in the compilation and production of a topographical or Cadastral Map, a number of ground co-ordinate control points are fixed by a ground survey party. The number of ground controls depend largely on the scale of map to be compiled (for large scale maps it may be necessary to fix at least four points on each photograph to ensure accuracy of scale). It is essential that these control points (or ground co-ordinates) are so arranged that they can clearly be identified on the photographs in order that a check may be made on the accuracy of the air photographs,

as an aid to the determination of tilt and variation of scale, if any, on the air photos due to any deviation from the vertical of the optical axis of the camera at the time the photographs are taken, accounted for by the fact that at present no camera stabiliser exists on aircraft which will ensure with absolute certainty that the optical axis of the camera is vertical at the moment of taking each photograph, and thus totally eliminate any tilt from air photographs (assuming for this purpose that the earth is flat or a horizontal plane).

Variation in Scale and Distortion of Plan Photographs

The weather conditions are mainly responsible for any variation in scale and tilt in photographs, accounted for to a great extent by the fact that fluctuating winds, and upward and downward currents of air are very frequently met with, and very often this happens at the moment of taking a photograph making it very difficult to keep an even keel and maintain a constant height when flying.

Types of Air Photographs

There are two distinct types of Air Photographs: Vertical and Oblique Photographs.

Vertical Photographs

Vertical photographs are taken with a camera fixed in an aircraft so that the optical axis of the camera is as nearly vertical as possible. This is done in order that accurate plan photographs may be taken of objects on the ground.

If the optical axis of the camera is not vertical at the moment a photograph is taken, the resulting photograph will show considerable distortion and differences in scale of the image at the four corners of the photograph, thereby rendering a very inaccurate plan view of the ground features.

Aerial Camera Mounting

In order to assist in the elimination of tilt in vertical photographs, a camera mounting in aircraft is designed, and by its use, owing to various means of adjustment incorporated in the mounting itself, greater accuracy can be obtained in the production of vertical Air Photographs.

1. Adjustments can be made to counteract fore, aft and lateral tilt of the camera. These adjustments are made when the aircraft has reached the altitude from which the photographs are to be taken and the aircraft is in correct flying position to maintain a constant height, which level flying position may depend and vary with the altitude from which the photographs have to be taken.

2. The camera itself can be revolved on the mounting, so that strips of overlapping photographs, each photograph correctly oriented to the line of flight, may be taken when the aircraft is flying into a cross wind and therefore drifting along the required line of flight.

Aerial Camera Sight

A camera sight is designed for use on aircraft, and can be operated either by pilot or observer when fitted in a position which gives a clear view vertically fore, aft, or laterally of the ground underneath. The object of the instrument is to secure accurate sighting of ground objects, in order to obtain the following information:—

The sighting of objects on the ground for vertical photographs.

To find the interval of time between the exposure of successive photographs in order to secure overlapping strips of photographs.

To obtain accurate sighting for lateral overlap of strips of photographs (when more than one strip of photograph is required to form a mosaic photograph of an area).

To determine the " ground speed " of aircraft flying at any altitude, and the approximate height of aircraft flying over any particular area of ground.

Overlapping Photographs

When a complete photograph is required of a long stretch of ground, *e.g.*, a road, river, or railway, etc., consecutive photographs must overlap. In addition the scale must be uniform, and the photograph free from distortion. A constant height must therefore be maintained when flying and taking the photographs.

Oblique photograph of hilly country.

Mosaic Photographs

A mosaic is a series of overlapping photographs assembled to form a complete photographic map of an area and is useful for giving a comprehensive plan view of the ground. Mosaics are most easily and quickly made by photographing lines of overlaps which, when joined together, form an unrectified " mosaic photograph " of an area.

A rectified mosaic photograph corrected for tilt or variation of scale covering large areas can be used for:—

Amplifying existing maps of large scale, say from 6in. to the mile upwards, and compiling maps to approximate scale; and to accurate scale when assisted by trigonometrical or other control points where the ground co-ordinates between each of the points are known, and can be identified on the photographs.

Oblique Photographs

An oblique photograph gives a view such as an observer sees from a hill, and hence although necessarily somewhat distorted they convey more information to an unskilled student of Air Photographs than do vertical photographs.

They give valuable assistance in working out the heights of embankments, and depths of cuttings, etc. Good results are obtained at a height of from 1,000

to 1,500 feet, with the angle of depression of the camera varying from 15 to 30 degrees.

Oblique photographs are also extremely useful as an aid to the interpretation of vertical photographs, inasmuch as the oblique photographs taken, present a side elevation and perspective view of the objects on the ground, and assist greatly in showing contours.

Vertical and Oblique Stereoscopic Photographs

In order to assist in the interpretation of Air Photographs, particularly vertical photographs, stereoscopic photographs may be taken, both vertically and oblique

Stereograms assist in the interpretation of vertical photographs by showing whether objects on the ground are convex or concave.

They also show the approximate height and depths of ground features.

They are of the utmost value as they show all objects above and below the ground plan in strong relief, thus simplifying the reading of the photographs, as the comparative heights and solid appearances of the objects readily disclose doubtful forms.

Contours and depressions show up clearly, and are a useful aid in constructing form lines in map compilation.

A stereoscopic photograph is obtained by super-imposing, by means of lenses, prisms, or mirrors, two photographs taken from different view points, and if the two separate view points are mounted about 2½in. apart, *i.e.*, the distance between the average human eyes, the result will be similar to that seen with both eyes open. The solid effect is obtained because the right-hand lens sees more of the right-hand side of the object than the left and vice versa.

When the ground is viewed from 5,000 feet upwards, no stereoscopic effect is obtained, because the angle the eyes make with the object on the ground is too small.

Aerial stereo photography differs from the ordinary photography in that from a great height, the object appears to the eye to be flat. In aerial work, therefore, relief is exaggerated abnormally. To do this the separation of the two taking points is increased beyond the separation of the eyes, and the greater the separation, the greater is the relief, and further, the higher the altitude from which the photographs are taken the more should be the separation between the taking points.

The most natural results are obtained with about 75 per cent. overlap of two photographs. If a very exaggerated effect is required a 30 to 50 per cent. overlap should be made.

It is essential that the two photographs be taken at nearly the same time, or the shadows will not agree. Two copies of the same photograph will not do, a fact which is not always realised. In photography, mounting and viewing stereoscopic photographs, it should be borne in mind that the best effect is usually obtained when the shadows of the ground features are falling towards one when viewed through the stereoscope.

The Interpretation of Air Photographs

The Examination of Photographs.—It is impossible in a short article to give even elementary instruction on the interpretation of Air Photographs. In order to become an expert on this subject, long and careful study of photographs is required, added to which the interpreter should possess a comprehensive knowledge of the particular type of ground features as seen from the air.

There are two methods by which the uninitiated may be assisted in the interpretation of Air Photographs:—

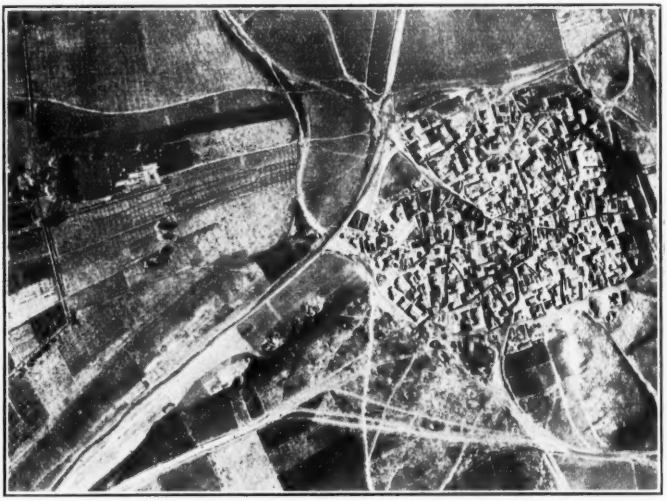
In the examination of the vertical (or plan) photograph by actually surveying the area photographed, from the ground. By this method, all doubt is set at rest as to the nature of the various ground features expressed in the photographs.

To assist a novice in the art of reading vertical Air Photographs which have been taken over an area which the reader has been unable to survey from the ground, the following procedure might be adopted with success.

Compare the vertical photographs with the oblique photographs of the same area, which will show the contours and side elevation of the objects.

Where great difficulty is experienced in the interpretation of unusual ground features, on vertical and oblique photos, then stereoscopic photographs can be used with great advantage.

Before examining photographs, it is necessary to form an idea of the appearance of objects from above, and to realise that objects will not appear under the same aspect as when viewed from the ground. This is due to the fact that only the tops of the objects appear on a vertical photograph. Every opportunity should



Nineveh from 8,000 *ft.*

be taken of studying on the ground objects similar to those which may be required to be identified on a photograph. During the actual examination of a photograph, the following important points should be remembered:—

1. The best available map should be studied with great care, so that the configuration of the ground and salient features are familiar.

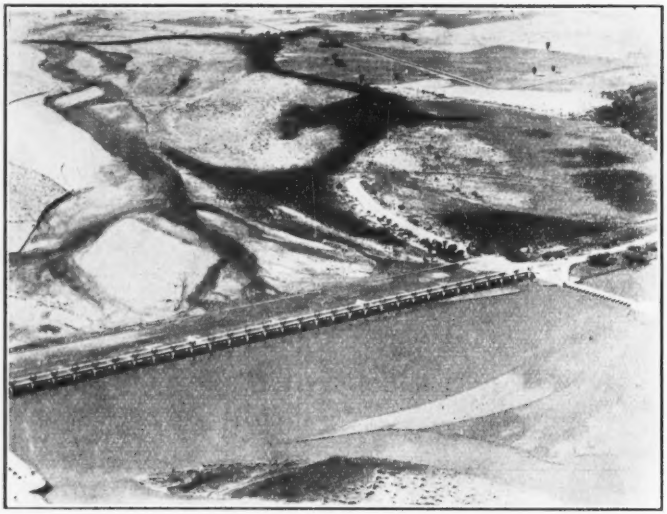
2. An approximate idea of the scale of the photograph should be formed by comparing the distance between two fixed points on the photograph with the same two points on the map.

3. Having ascertained the position of the photograph on the map, and the scale, it is necessary before examining the detail of the photograph to ascertain the direction of the light. This can be done by studying the direction in which shadows are thrown by the trees, houses, etc. The photograph should then be held so that shadows fall towards one. A thorough familiarity with the effect of shadows is absolutely essential to the discovery of the direction of light, and in a greater degree to the correct study and easy interpretation of Air Photographs. A careful examination of the shape and length of the shadow cast by an object not only discloses the nature of the object itself, but affords a valuable basis for estimating the dimensions of other objects shown on the photograph; it is also possible to determine whether an object is convex or concave.

In examining a photograph, every possible interpretation of any particular detail should be borne in mind. The various probabilities must then be taken into account. It must then be decided whether there is sufficient evidence to justify a definite decision. It must always be remembered that one photograph by itself may give little information, but when read in conjunction with other photographs, intelligence summaries, etc., much valuable information of either a positive or a negative character may be obtained.

Survey Flying Organisation

In order that the duties of pilot and photographer and the difficulties which are met with and have to be overcome where possible when carrying out an air photo survey, there must be a thorough and complete understanding between the two. A system must be laid down whereby the pilot and photographer work



Sand banks under water.

together. It is hopeless to expect successful results otherwise, in other words team work is essential.

The duties of pilot and photographer are clearly defined. Before proceeding on a survey, both pilot and photographer should confer together as to the procedure they are to employ when photographing an area. The pilot is responsible for the actual flying of the aircraft, and it is his objective to fly his machine straight and level and to maintain a constant height when flying over the area to be surveyed. This requires very careful attention to the instruments in the aircraft, such as compass, altimeter, and air-speed indicator, etc. A careful check should be kept on drift when flying into a cross wind in order that there is no deviation from the true course. When overlapping photographs are being taken in parallel strips, care must be taken in lateral sighting on the lines of flight to see that the strips of photographs when taken overlap each other.

The photographer's duties are numerous, and amongst these duties in addition to the manipulation of the camera, it is necessary to determine the interval of time between the exposure of plates in order to get a fore and aft overlap on each photograph. To enable this to be done accurately, the following factors have to be

taken into consideration. Altitude and ground speed of the aircraft, focal length of lens and size of photographic plate used must be known, the interval may vary from time to time depending on wind velocity conditions.

Alterations may often have to be made in the speed of exposures on plates; this will depend on the nature of the ground features being surveyed and volume of light on the objective. Very often light filters have to be used. These light filters (or screens) are fixed on the camera between the objective and the plate to serve a double purpose—

To penetrate and if possible eliminate on the photograph any haze which may appear in the atmosphere.

To give colour correction in order that the utmost detail and colour value in monochrome of objects on the ground may be clearly defined on the Air Photographs.

Tea gardens.

Procedure on Air Photo Survey Reconnaissance

The usual procedure on each day of survey reconnaissance is as follows:—

1. The aircraft takes off from its base on days when weather conditions are favourable for photography. The load consists of pilot, photographer, camera (photographic plates or rolls of film, and all instruments and camera sights, etc.), required for the survey.

2. The aircraft is headed for its objective, the area to be surveyed, which may be quite near or miles away, depending on which area is being surveyed at the time. Height is gained whilst proceeding to the area. At the height from which the photography has to be done, the level flying position of the aircraft is fixed and the camera sights and light filters, etc., adjusted. Photography is then carried out, the aircraft flying in parallel lines of flight, and overlapping photographs are taken to form a photo mosaic of the area surveyed. If the weather and light conditions are ideal, three or four hours' actual photography is generally done and about 200 to 300 photographs taken on each survey reconnaissance, covering an area approximately 80 to 100 square miles on each flight. The num-

ber of photographs taken on each flight of course depends entirely on duration of flight, the altitude from which the photographs are taken, the size of plate or film and focal length of lens used. On completion of the photography the machine returns to the base, and on arrival the exposed plates of films are handed over to the photographic section and developed. The negatives are annotated and prints made and joined together in the form of a rough unrectified mosaic covering the area photographed. This is done as a guide to show if there are any gaps in the photography of the area, which might be caused by camera trouble or any deviation from the correct parallel lines of flight, etc.

Completed mosaic of Mandali.

Ground Organisation

In order that the survey may be a success a great deal has to be done by the ground staff, which include ground engineers and mechanics who look after the overhaul of the aircraft; darkroom photographers to carry out the development of plates or films and printing and enlarging from the negatives, which may number thousands, depending on the extent of the survey. Draftsmen are necessary for the work of translating and transferring the detail from the Air Photographs into map form, using the usual conventional map symbols.

When seaplanes are used for air photo surveys, very often a temporary slipway and hangar for the seaplane have to be erected in the field.

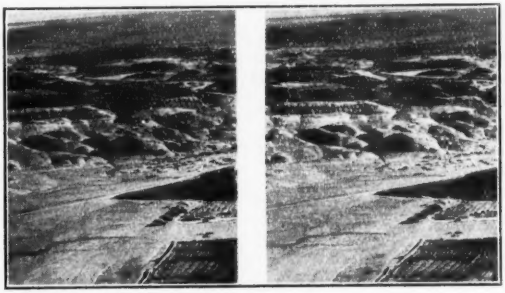
An air survey party of the present day is a very mobile expedition. Surveys have to be carried out under every conceivable condition of climate and light. Operations have to take place over cultivations, jungle and swamps, in extremes

of heat and humidity and sometimes over mountainous country. Occasionally it is necessary to convert the aircraft from a long machine to a seaplane or vice versa, depending on the aircraft landing conditions of the survey.

Air Photograph Cadastral Mapping

At the end of 1928 and early 1929, under the direction of the writer, over 4,000 square miles of country in India was photographed from the air by means of vertical air photography for the purpose of providing maps for Land Settlement and Revenue purposes. In addition to this a series of river crossings surveys were done for Indian Railways.

Altogether about 20,000 air photographs were taken, and the whole of the air work was completed inside a few months, during which period about 60 per cent. of the time the weather was suitable for air photography and the remaining 40 per cent. unsuitable on account of rain, low clouds, etc. The photographs were taken to a scale of approximately 6in. to 1 mile, with a 55 per cent. overlap on each photograph fore and aft on the line of flight.



Stereoscopic view of Kifri Aerodrome, taken from a height of 1,500 feet.

Assuming areas of 5,000 or more square miles have to be mapped for Land Settlement, an expedition may be divided up into four sections:—

(*a*) Flying and photography.
(*b*) Ground surveyors (traverse party).
(*c*) Land settlement survey party.
(*d*) Map production.

To centralise the work, a headquarters is fixed, which consists of an aircraft landing ground, suitable buildings (with, if possible, water and light installed); these buildings to be used as photo section, drawing office, workshops, headquarters office and accommodation for ground staff (European and Native), which includes officers, mechanics, clerks, draughtsmen, surveyors and photographers. If buildings are not available, it may be necessary to construct same with whatever materials are at hand, which may mean mud huts, shacks of leaves or grass, and sometimes dug-outs may have to be constructed.

If the survey covers a very large area, advance bases with suitable landing grounds have to be found and sometimes made.

It is also necessary to provide land or water transport, mechanical or otherwise, for local use, and to keep in communication with the advance bases. The headquarters base is generally situated as near as possible to the centre of the sphere of operations, and the other advance bases may be anything up to 100 miles distance from the headquarters.

After each photographic flight all exposed plates or films are handed over for development and printing, accompanied by a photo report giving full particulars of the flight, together with a rough sketch map showing approximately the area covered by photographs on each flight. The photo report would give such information as area photographed, giving direction of photo stripping, and approximate boundaries of block photographed. Altitude from which the photographs were taken, weather conditions for flying and photography, etc., etc.

In the case of 16in. mapping the photographs are generally taken to an average scale of 6in. to 1 mile, and afterwards enlarged to 16in. to 1 mile ($2\frac{1}{2}$ times enlargement).

On receipt of the exposed plates or films they are immediately developed, dried, and each photograph is given a serial number.

Each survey flight or block is given a letter, A to Z.
Each spool of film in every flight is given a number
Each strip of photographs in every flight is given a letter (A to Z).
Individual photographs in every strip are given a serial number.

The negatives are then printed and roughly mosaiced and a complete record made and registered of the flight, together with a key sheet for the location of all photographs taken on the survey. The next stage is to photograph the rough mosaic, and produce an enlargement to a scale approximately 1in. to 1 mile. These rough 1in. mosaics are then used for two purposes (1) as a guide to the pilot and photographer showing the boundaries already photographed on the survey flight and also as a guide to the ground survey traverse party in assisting them to determine the lines of traverse when marking ground co-ordinate control points on the photographs of the survey.

Ground Survey Traverse Party

The ground survey traverse party is supplied with a complete set of overlapping vertical photographs of the survey. These photographs are taken into the field for the purpose of marking on them the ground co-ordinate control points to be used in the survey for purposes of accuracy of scale.

Main Circuit lines of traverse are generally run on the overlapping portions of adjoining flights (or blocks) photographs.

Sub Circuits run on the overlapping portion of two adjoining strips of photographs (roughly a mile apart).

If the length of a sub-traverse of a particular flight (or block) is more than four miles, then it may be advisable to run a cross sub-traverse on the middle of the flight, starting from one main circuit and closing on the other, connecting traverse stations of the minor traverse of that flight. On each photograph at least four traverse stations should be fixed on well identified spots, such as open and unshaded junction corners of at least three fields which are correctly identified and clearly visible and recognisable on the photographs.

On completion of the ground work the marked photographs, together with traverse plot and field sheets of the whole area, are handed over to the map production department.

Land Settlement Survey Department

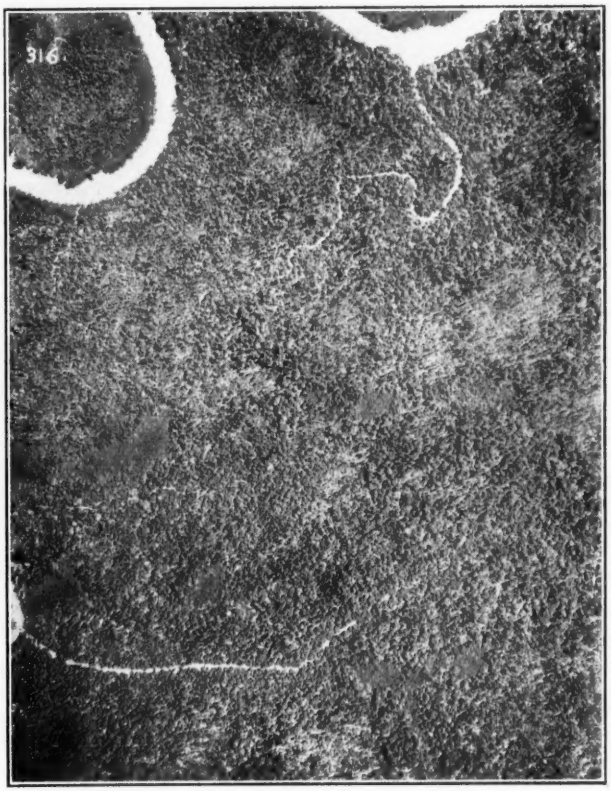
This department is supplied with a complete set of 16in. scale enlarged photographs of the area surveyed on which to ink up all the boundaries of villages and holdings, and insert such other information as may be required by the department for the production of the maps, which may include the addition of detail obscured on the photographs, particularly around villages and along main roads which generally abound with trees and tree shadows, making it very difficult and sometimes impossible to distinguish the ground detail.

In such cases it may be necessary to line up on the photographs by traversing the hidden detail, entering in a field book full particulars.

On completion of this work, the lined-up photograph enlargements are handed over to the map production department.

Map Production

On receipt of all the ground traverse data, which includes the ground co-ordinates marked on the photographs, field sheets and traverse plots of the area surveyed and the inked-up enlargements and field sheets from the land settlement, the work of map production commences.



Forest country taken without shadows.

In the first instance all the photograph negatives are marked with the control points and placed in the rectifying enlarger. The photographic image is projected to the scale of map required (namely 16in. scale) and rectified for tilt by super-imposing the control marks on the negatives with the ground controls on the plotted sheets, measures being taken to prevent distortion of the paper on which the enlargement is made (the process of rectification is best carried out before handing the enlargements to the land settlement department for inking up

and thus avoiding a duplication of enlargements and incidentally cutting out an extra process).

The enlargements are then handed to the mapping section and the detail on the photograph traced on to sheets of celluloid, using the usual map conventional symbols.

On completion of tracing the map sheets, they are then printed by the Vandyke or similar process, either in sheets of individual villages or in consecutive map sheets throughout the whole survey.

Air Photography of Forest Areas

In order to compile a topographical map of forest areas by means of Air Photographs without obscuring detail, most of the photographs are usually taken about the mid-day hours, say between 10 a.m. and 3 p.m., in order to avoid the long shadows cast by the trees, etc., during the morning and later afternoon and which would tend to obscure quite a lot of detail as well as a number of the control points fixed by the ground survey party on the banks of rivers and creeks, that is, assuming it has been decided to fix the control points before the photographs are taken. As a rule it has been found to be more advantageous and much more satisfactory to fix the control points after the photographs have been taken on easily identified features on the photographs. By this method the procedure is to take the photographs into the field and mark the control points on the photographs and at the same time enter the co-ordinate values into the field book and later plot out the control.

In order to obtain results in photography which would show up the details of types of trees, etc., to the greatest advantage, the best time of day to take these photographs would probably be in the morning or afternoon, as at these times there is much more cast shadow than during the middle of the day, with the result that the shadows would tend to show up the trees in relief and give almost a stereoscopic effect, and make them much easier to distinguish. It is sometimes most difficult to secure a good aerial photograph on account of prevailing clouds, cloud shadows and haze, very often so dense that a very deep light colour screen has to be used in order to penetrate, and, if possible, eliminate the haze. All this is detrimental to securing excellent photographs, as, on account of clouds and haze, objects appear flat and lacking in relief because of the absence of direct sunlight and shadows thrown by the trees, etc., on the ground.

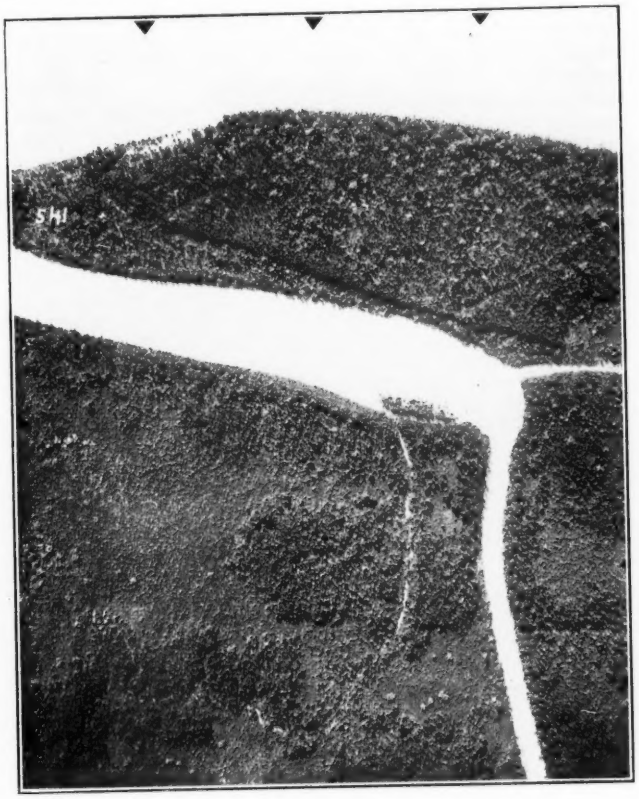
Results and Information Obtained by Means of the Air Photographs

By means of the Air Photographs accurate information can be obtained of many things, in particular details which could not have been obtained by the ordinary ground survey methods chiefly on account of the inaccessibility of different parts of the regions surveyed which are mostly covered by jungle and tall trees, narrow creeks and swamps which abound in profusion throughout these areas, to such an extent that it is well-nigh impossible to get the necessary detail for a topographical map.

Forest Stock Maps

It is certainly a most difficult problem to locate the position regarding the stocking of timber by the usual ground methods, and it is a long and laborious task. By means of the Air Photographs this task is simplified and information can be obtained by the examination of the detail shown on the photograph which greatly reduces the process of going over very carefully on the ground the various forest reserves.

Furthermore the existence of sand banks in rivers, creeks and along coastal lines, in some cases partly or entirely submerged is very often clearly shown on photographs and would be well-nigh impossible to locate by means of ground survey alone. In the short space of time taken to complete a comprehensive survey over difficult country such as mangrove forest, swamps, etc., done by means of Air Photographs, as against ground survey methods in the compiling of a map to any scale is a matter of months as against years by the ordinary ground survey methods. Added to this the enormous amount of detail obtained by Air Photographs at small cost which could never be got by ground survey except at enormous expense.



The effect of shadow over forest area.

By means of Air Photographs much useful information can be obtained on prospecting for mineral resources in a country, provided the most suitable photographic plate and colour light screens are used to reproduce in monochrome the colour values of the ground features. In this respect Air Photographs should prove of great value to engineers and prospectors as well as to archæologists, etc.

Air Photographs, apart from their use in the making of maps, can be used in many other ways, both for general information and for use in military operations. In many instances an Air Photograph conveys information of the past, present

and future. Take as an instance the coast line and the course of rivers (which in many parts of India and elsewhere are liable to change their course from time to time).

From Air Photographs it is possible to determine sometimes where the river or coast line was originally, or at least many years ago, where it is to-day, and by a careful study of the ground features, there may be seen indications as to where it is likely to be in the near future.

Cost of Air Surveys

There has been from time to time much controversy regarding the cost of aerial surveys and even at the present time one cannot state with any authority a flat rate for the production of maps made from Air Photographs. There are many factors to be taken into consideration in estimating the cost of mapping from Air Photographs, so much depends upon, firstly, the scale of map required; secondly, the local conditions governing a survey, whether the survey is large or small, compact or isolated, etc., etc. In the writer's opinion, it is considered that if original surveys were large enough and continuous, and within reasonable distance of an expedition's headquarters, these surveys can be made to pay all concerned and could be carried out at less cost and time than by ground survey methods.

REVIEW

Standard Specifications for Benzole and Allied Products, 1929
Published by the National Benzole Association. Price 6/-.

The importance of standardisation as applied to commercial products has in recent years become increasingly apparent, and recognising this factor the National Benzole Association invited and secured the collaboration of a strong and fully representative committee of the Coal Gas, Coke Oven, and Tar Distillation Industries.

This committee set out to standardise specifications for motor benzole and the other constituents of the light oil fraction of coal tar, and this volume represents the results of their labours.

The book is divided into two parts, Part I. dealing with definitions and specifications, and Part II. with methods of testing.

From the aeronautical engineer's point of view, perhaps the most interesting item in Part I. is the specification for motor benzole, as the latter product has had a very considerable influence on aero engine design.

Modern aero engines require a fuel with a high anti-knock value in order to obtain the requisite overall efficiency, and in the effort to supply this, recourse is being made to all sorts of anti-knock dopes, both metallic and otherwise, and as a consequence there is a tendency to minimise the importance of benzole; but in view of the many factors which arise before standardisation of such dopes can be made, it is considered that some years will elapse before we can afford to ignore motor benzole.

It is interesting, therefore, to compare the specification for this product embodied in this volume, with the original British Engineering Standard Association Specification No. 135 issued in 1921.

There is comparatively little difference, the main features being a slightly wider distillation range and a higher freezing point in the case of the more modern specification.

Anyone who has tried to purchase motor benzole in large quantities to the earlier specification will appreciate the importance of these modifications.

The remainder of Part I. is devoted to specifications for various varieties of toluole and xylole and coal tar naphtha.

In attempting to produce a standard specification for any product, one of the most important factors is to standardise the methods of testing, otherwise the divergences in methods and results are liable to render such efforts nugatory. In this respect the committee has had the advantage of being able to utilise the methods of testing prepared by the Standardisation of Tar Products Test Committee in advance of their publication.

Part II. gives full details of the various methods of test and particulars of apparatus.

The whole volume is of great interest and may be considered a useful companion to its forerunner in the petroleum industry, viz., the Standard Methods of Testing of Petroleum and Its Products.

F. A. F.

CORRESPONDENCE

Dear Sir,—In the paper published on " R.100 " in the February issue of the Journal by Mr. R. B. Brigham there appear such a number of inaccuracies, both on R.100 and R.101, that it is difficult in a short letter to correct more than a small percentage of the errors. Outstanding examples, however, are quoted below.

On page 184 it is stated that tubular girders in R.100 are made from material varying in gauge from .032in. to .064in. The helical duralumin tubes incorporated in the structure of this ship vary in gauge from .022in. to .056in.; no .064in. tube has yet been constructed by the Airship Guarantee Co., Ltd. On the same page it is stated that the tubes for the longitudinal girders vary in length from 45 to 50ft. The whole of the longitudinal girder tubes in R.100 are 42.37 feet in length except those of Bay O, which are 22.21 feet long.

On page 185 reference is made to a wire mesh " which encased the ship " and is " wrapped round the ship." No such mesh exists, though it is possible that a reference is here intended to the gasbag mesh wiring.

On page 186 it is stated that " the elevators and rudders—were operated by four small variable gear boxes. The ratio of the gears varied from 30 to 1 to 300 to 1." In actual fact, seven gear boxes are used on the two rudders and six on the two elevators. The gear ratio varies from 98 to 1 to 330 to 1.

On page 187 it is stated that the three power cars of R.100 weigh 7½ tons in all. The correct figure is 9.6 tons, the weight of the reverse gear boxes being 750lbs. instead of 300lbs., as stated in the paper. On the same page the description of the R.100 water ballast system is entirely fictitious.

On page 188 it is stated that " the external fabric covering the ship was of rubberised fabric." No rubber is incorporated in this pre-doped material. On the same page it is stated that the mooring gear was designed to withstand a gale of 100 miles per hour. This case formed no part of the design conditions for the ship.

It is with considerable regret that I write to point out these errors to the readers of the Journal. Technical literature upon the design of modern rigid airships, however, is so scanty that the publication of this paper may well have misled a number of interested persons both in this country and abroad.

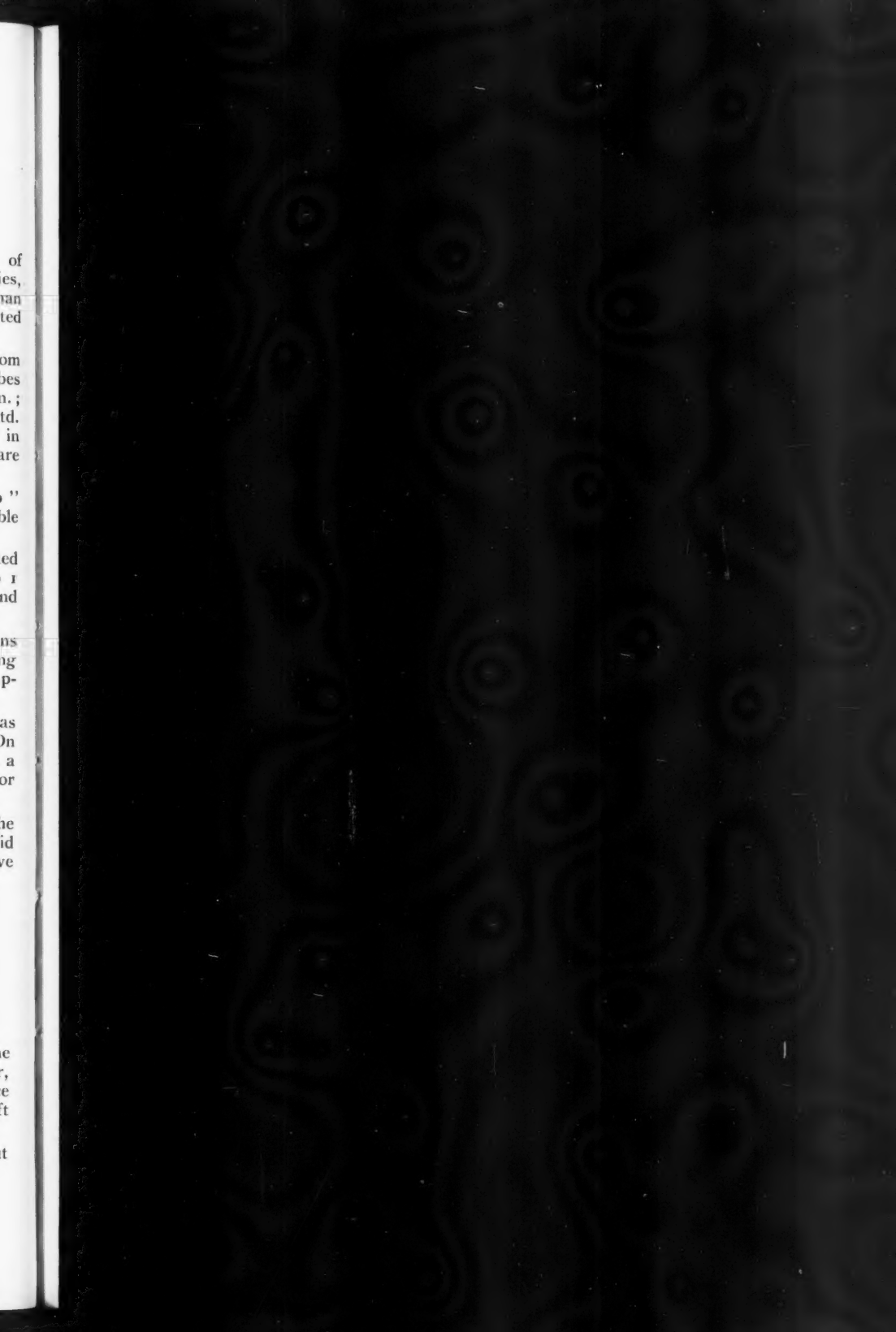
Yours faithfully,

N. S. NORWAY.

The Airship Guarantee Co., Ltd.,
Howden, E. Yorks.

Dear Sir,—With reference to a suggestion in a recent paper that ethylene glycol is a suitable medium for the cooling of aero engines in place of water, may I draw your attention and that of the lecturer to the fact that this substance is highly inflammable and might materially increase the fire risk to the aircraft especially in the case of a crash.

Another suitable liquid is glycol triacetine, which has a boiling point of about 250°, but this substance also suffers from the defect of inflammability.

Yours faithfully,

W. O. MANNING.